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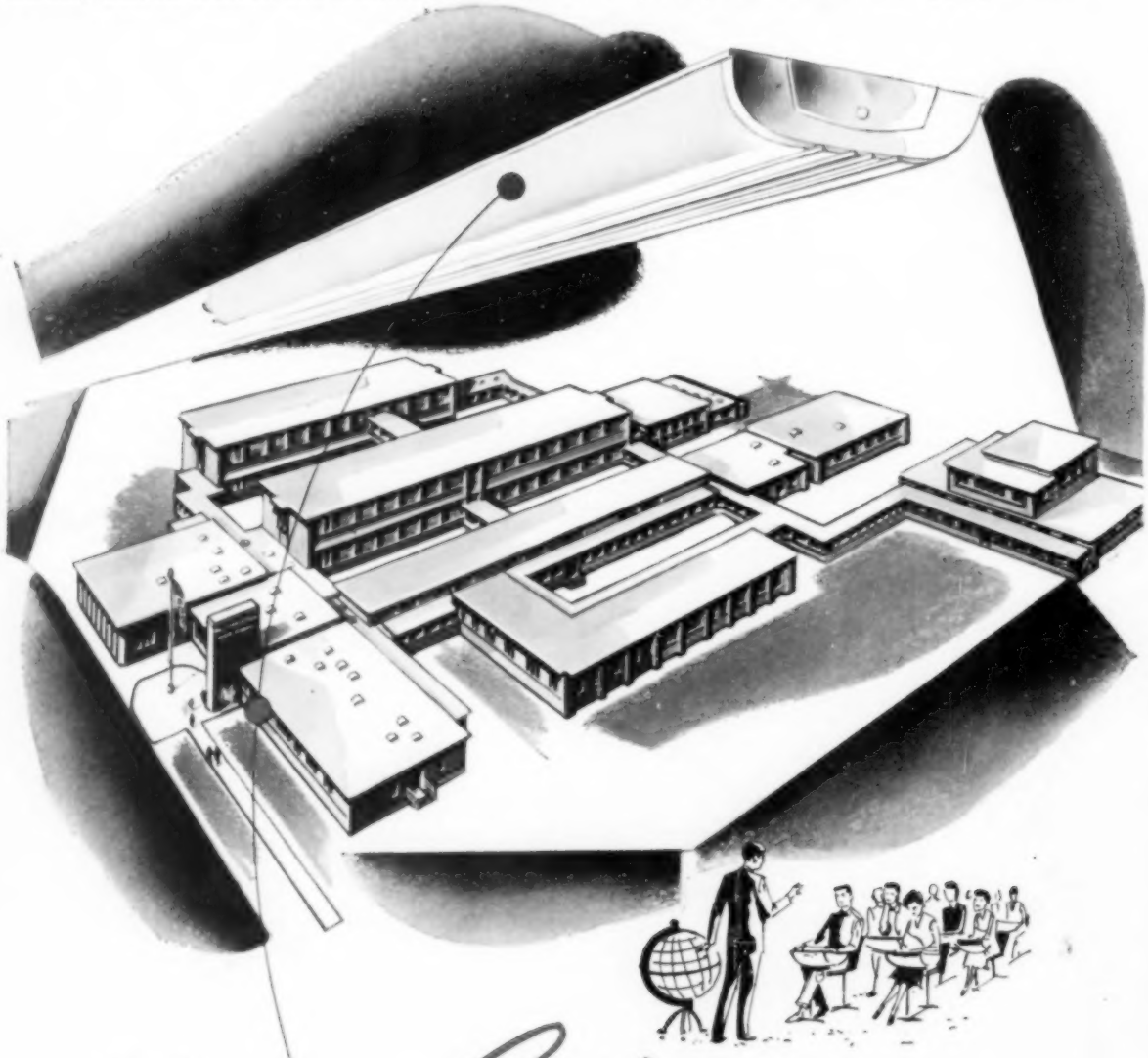

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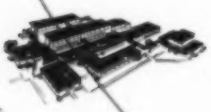

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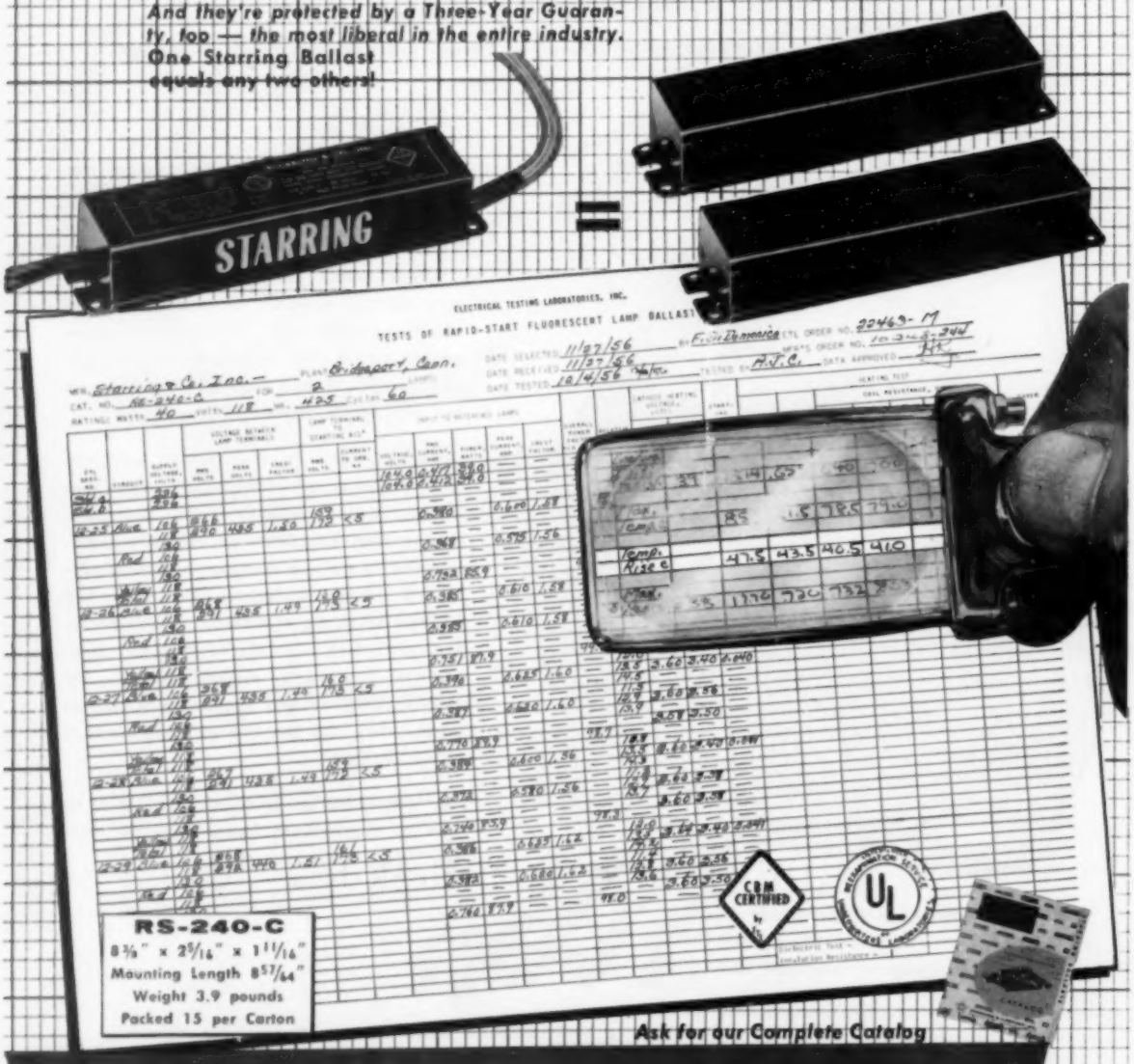

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May 1957

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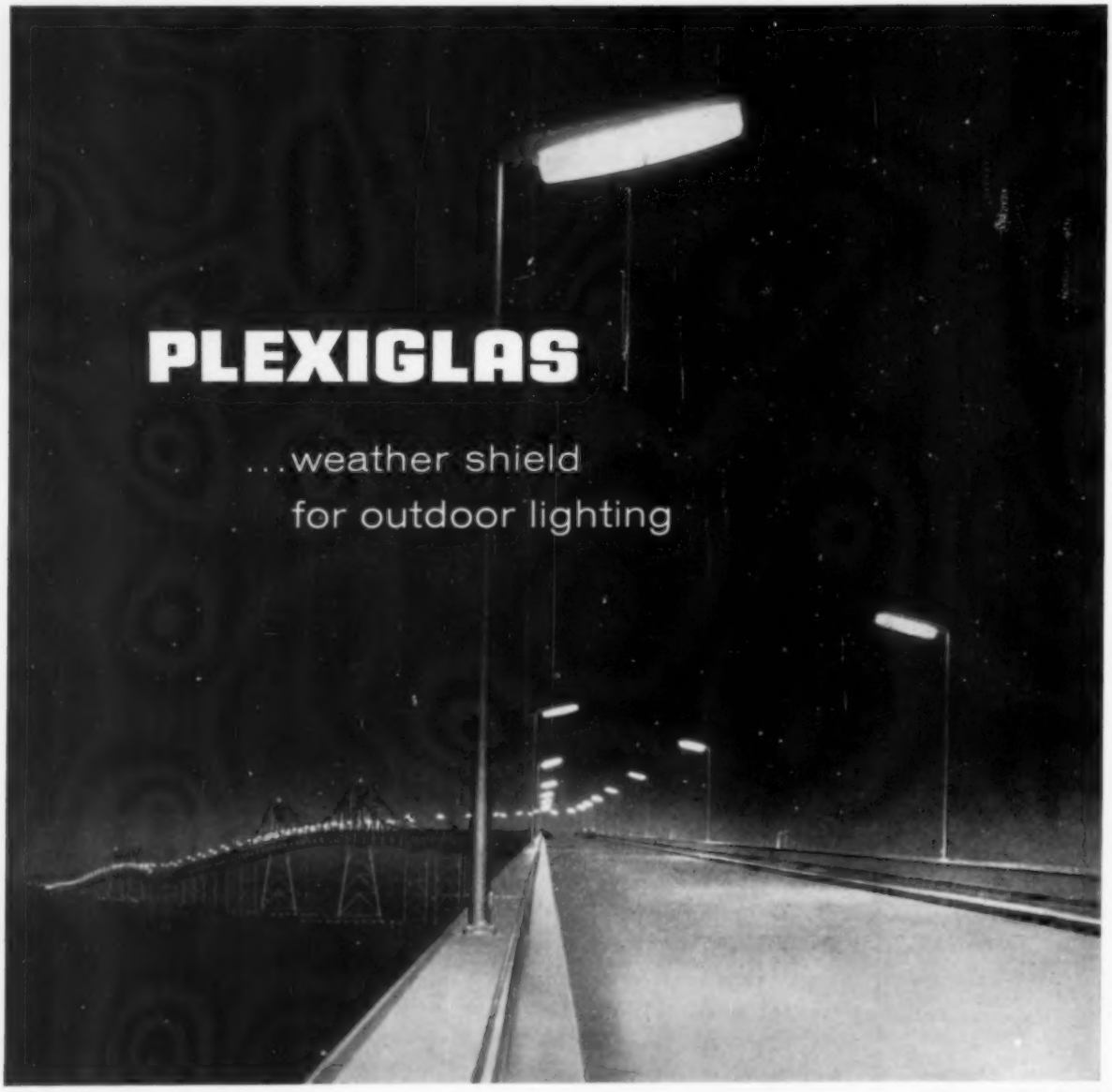

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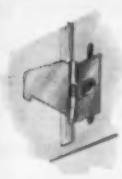

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Great Britain and Continental Europe Research on Visual Comfort

By R. G. HOPKINSON

Research on visual comfort and associated problems has taken somewhat independent courses in countries on the east side of the Atlantic and in America. In England more emphasis is placed on the factors which govern the appropriateness of lighting for its purpose, and greater strides have been made to integrate color of interiors with lighting. The importance of planning lighting in terms of what we see rather than what the photometer measures has been stressed; this involves the careful determination of adaptation effects. Controversy on the use of fluorescent lighting has sometimes been strong, but in general most fears are now allayed.

THE STEADY COURSE of lighting research on the eastern side of the Atlantic was interrupted and almost completely diverted into war purposes during the 1939-45 period. Publication of new work ceased, except where occasionally work completed before the outbreak of war was hurriedly tidied up to help to fill attenuated publications in order to maintain some sort of continuity. At the end of the war, there was a vast mass of work, hitherto classified in secret categories, that was pressing for publication in journals with a fractional allowance of paper. Much useful work was completely crowded out and never saw publication at all, while the small fraction that did eventually get printed appeared in an abbreviated form, often as a consequence unsatisfactory for subsequent reference. It was not until the early 1950's that European publication in the field of lighting and vision began to march in step with the pace of the work. The foundation of several new journals, particularly *Acta Optica*, and the revival or metamorphosis of several others known before the war, aided this return to normality. The most recent to attract attention is the Russian journal *Svetotechnika*, which unfortunately very few of us can read.

It is against such a background that my paper is prepared. In the U.S.A. you managed by a tremendous effort to maintain a continuity of research and publication which deserved and received our wholehearted admiration, and you have kept the pace going with no apparent discontinuities, so far as the reader of your technical literature can detect. On our side we are continually having to pick up pre-war theories, and I must consequently ask you to have patience with us if we keep on referring to outstanding papers of the '30's, to Lythgoe on visual acuity, Stiles on glare, Beuttell on the analysis of lighting, Patterson on lighting principles. These workers laid the foundations of our present studies.

This paper is not going to be an impartial review — I must make this clear at the outset. An impartial review could have been better done by a professional information officer. If one works in a field of research as I have done, for twenty years, controversies inevitably arise between various workers and laboratories. These controversies make for much of the interest in the work, but anyone involved in them cannot be expected to present an unbiased picture, and I believe that it is far better not to claim to have made the attempt.

The main recent development in Europe, as I see it from the Building Research Station at Garston, in England, is the importance now being given to the lighting of the environment; as Crouch has it, "the provision of the luminous environment." Europe has almost recovered from "foot-and-candle disease." We notice this at Building Research Station, because whereas when we started up our "subjective" work in 1947 after the war break we were considered unorthodox and even rebellious, we now find ourselves carried along in the main stream of events, and our work is acceptable to all but the most conservative. Development in Europe has appeared to follow on yours initially, but nevertheless our approach is to some extent different, as can be appreciated from a study of the Codes of Practice of the French and later of the British Illumi-

Part I of a lecture given at Cornell University, Ithaca, N. Y., on September 15th, 1956, to a Symposium on Visual Research held by the Illuminating Engineering Research Institute of the U.S.A.
AUTHOR: Dept. of Scientific and Industrial Research, Building Research Station, Garston, Watford, England.

nating Engineering Societies. We try to place more importance on factors which lead to variety and freedom in lighting, even though so far we cannot put figures on all of them. Perhaps the opposite ends of the scale are represented on the one hand by the work of Hesselgren in Sweden, of Kalff in Holland, and of my own colleague Gloag at the Building Research Station, where aesthetic considerations are uppermost, and on the other by the one-time 3:1 luminance ratio standard over here in the U.S.A., where, as someone once put it, a man in a black suit would be a glare source. You have moved away from that position and are working towards the ideal solution, and we are working towards the same solution partly from the intangible and indefinite position of the aesthete and partly from the firmly entrenched position of the footcandle engineer.

The direction which European work on visual comfort is taking is indicated by the strong pressure which was brought to bear on the C.I.E. at Zurich in 1955 to form a separate committee to deal with "Pleasantness in Lighting." Nobody was quite sure what term to use, but the intention was clear, to form a group to study the more aesthetic factors in lighting, and so to leave the physicists, engineers and physiologists in their back rooms with their endless discussions on glare formulae and statistical significances, for it was felt, perhaps rightly, that the discussions were holding up the development of the subject. It remains to be seen if this move will, in fact, speed the work. Relatively little has been published in the field of "Pleasantness in Lighting," so agreement should be easy, but I doubt if it will be. Hesselgren's thesis contains a great deal that is valuable, and is perhaps the most complete statement available, but it is difficult to read because of the obscurity of the presentation in some of the sections which deal with fundamentals. Kalff's papers are more specific, because they make less attempt to formalize the basic principles. Gloag has published very little, but in the field of color two of his papers state an approach which is capable of considerable development.

Gloag deliberately avoids too rigid a characterization of lighting, preferring to consider each situation on its merits, and to provide both color and light appropriate to the character of the building. He appears to attach a special meaning to the word "character" in this context, embracing not only the aesthetic appeal but also concepts of visual efficiency and comfort hitherto associated more closely with the engineering approach to lighting. His work has been so far essentially practical. He has designed the color and lighting for a number of buildings, and his philosophy can be discerned from these buildings.

Gloag divides lighting situations broadly into two categories, the "dramatic" and the "suffused." The typical "dramatic" situation is one in which either color, or light, or both, produce a strongly delineated dominant center of attention, in an environment characterized by strongly directional light and deep shadow, an absence of diffused and inter-reflected light, and a marked difference in the colorfulness of the main centers of attraction and of the subsidiary environment. The typical "suffused" situation relies on inter-reflected light and absence of strongly chromatic color for its effect, the 3:1 ratio situation in fact, with the essential difference that Gloag advocates the use of limited areas of strong color in the shadowed areas of a "suffused" situation to modify the effect where appropriate.

This is an inadequate statement of Gloag's approach, which depends, as does that of Kalff and Hesselgren, on personal development for its working out. I think that we engineers may have to accept that all these studies may never have as their end point a formalized set of working principles. The principles may have to be worked out by someone other than the original workers, from a study of their practical realizations. Waldram has attempted another approach to the problem. He accepts that it is the architect who will always decide the qualities of a lighting situation, by no matter what means — intuition, precept, architectural rules, no matter. The engineer's job, according to Waldram, is to realize these requirements, just as the structural engineer makes sure that the building will stay up. Waldram translates the demands of the architect, through my 1941 scale of apparent brightness first to luminances, then to illumination and reflection factors, and finally to light distributions and positions of light sources. This seems an eminently logical process, and it will be of interest to see how his method will work out in practice.

At the Building Research Station, we have refrained from a too rigid application of the apparent brightness concept, although of course my data have been always available when necessity has demanded the assessment of adaptation effects. It will be interesting to see if Waldram can succeed with a numerical approach to the aesthetics of lighting. In my paper at Boston, this concept of apparent brightness is discussed ("Assessment of Brightness," I.E., April 1957) and it is shown there that at the levels of modern interior lighting, apparent brightness and luminance are not so very different. Apparent brightness certainly ought to

be an everyday working tool of our profession, but more especially in situations of low luminance where adaptation plays such an important part. Our approach at the Building Research Station has been to employ the concept of apparent brightness for first appraisals, but to place our emphasis on the less numerical aspects of the subjective side of light, and this requires the use of models, in which we place great faith.

At the Building Research Station we make extensive use of models because we believe that only a certain amount of the job can be done by calculation, and the rest has to be done by inspection and study. Now that may seem to be a retrograde step, it seems so unlike an engineer to have to set up a model to see whether his predictions are going to be fulfilled. But there are so many things in the lighting of an environment which just simply cannot be predicted by calculation; you have to have a look at them and make modifications and alterations. And it need not be a long job. We have solved the problem by taking advantage of the fact that these days there is a great deal of architecture which is done on the principle of modular coordination and so we have built a "modular model," consisting of a large number of small components made to the scaled-down module, so constructed that they can be fitted together quickly. In fact we have set up a model of a lighting installation and made the complete survey between morning coffee-break and lunch-time. I doubt if anybody could do the calculation as quickly as that, and of course we find out by this means a great deal more about the installation than ever we could by calculation.

The most important thing that seems to be missing from lighting research at the moment is: what are the things which govern *attention*. I have searched the psychological literature and I can find very little which helps us here. And I think we are on to an entirely new field. As you know, the literature of painting is full of recommendations and suggestions and ideas on the things that govern attention, but they are qualitative only. Physiology speaks of the "fixation reflex," that is to say the characteristic which makes the eyes turn toward bright things in the field of view. The biological sciences refer to "tropism," the moth around the candle or the way plants in a room will grow toward a window. Organisms, low and high, have an attraction for light. Light is a thing which helps to determine attention, and we know that by direct observation. When you drive along the highway, the opposing car headlights are a compelling source of attraction, and you have to exercise most strong will-power to avoid looking at them. We know that a colorful area in monotonous surroundings commands attention. But there are other things, insignificant things like a spot of light on a specular rim of a luminaire, the interruption in the regular pattern of a wallpaper by inaccurate hanging, which compel attention. The lighting engineer needs to know exactly what are the features of the scene which command attention if, for example, he is to design local lighting to focus attention on the work, or, on the other hand, if he is to avoid distraction from the work caused by bright light sources or reflected images.

A powerful technique in the study of the visual field has been provided by Shackel, who has developed the corneal-retinal potential method of studying eye-movements. Shackel's method is basically the same as that used by Carmichael and Dearborn, and many others in the U.S.A., but by a succession of refinements he appears to have achieved a more stable and accurate technique than hitherto. With the aid of Shackel's method, the pattern of eye movements in a given visual field can be observed, so that, for example, the distraction of the eyes from the work to a reflected image can be recorded objectively. The technique does, however, demand that the subject must be constrained by the electrodes placed above, below, and to each side of his eyes. This is not such an ordeal as it appears, and it can be tidily arranged so that the subject is relatively free to move about at or near his job. This method is being used by Shackel himself, and also at the Applied Psychology Unit at Cambridge where Shackel started his work, for a study of scanning and searching movements with different forms of visual task.

At the Building Research Station we are studying the problems of attention by a direct cinematographic recording. The method is less elegant than the corneal-retinal potential method, but it has the advantages that no constraint need be put on the subject, and that it avoids the need for expensive electronic equipment and the staff to build and maintain it, a major consideration with us. The method depends for its success on the fact that the subject must be quite unaware of the purpose of the experiment. If he knew that the movements of his eyes were under investigation, his pattern of eye-movements would inevitably suffer some change. He therefore has to be led to believe that he is performing an entirely different experiment. The subject sits down between two mirrors curved to enable an image of the subject's own field of view to be photographed at the same time as his eyes. He looks at a visual task, *e.g.* a chart 10 inches square containing 48 Landolt rings each 1.5 cm. in diameter seen 10 feet away. There is a small central aperture in the chart through which the camera

photographs the subject and the mirrors. This aperture appears black to the subject, and he cannot see or hear the camera. Cinematographic records are made of various arrangements of the field of view, that is, with general lighting in the room, with general lighting plus local light on the visual task, with glare sources of various size and luminance seen together with or without local lighting, and so on.

The results are interesting, but not altogether systematic, because certain personality factors come into the picture which tend to mask the "phototropic" effects.

It is interesting that these personality factors link up with those reported by Witkin in his studies of spatial orientation. Setting aside these factors, we find that the method confirms that (a) attention remains on the work more effectively if it is locally lit than if it is seen only in general illumination; (b) a light source in the field of view distracts attention from work; (c) the gaze is fixed more readily on a large source of low luminance than on a small source of high luminance, the eye movement in the presence of a large source of low luminance consisting of a series of relatively slow traverses towards the source, where the gaze is held for many seconds at a time; (d) the eye movements in the presence of a small source of high luminance consist of a series of jerky darts towards the source and away again, the gaze never being held for more than a fraction of a second at a time.

It is too early yet to go further in detailing the conclusions from the work. We also intend to make direct subjective judgments of the degree of distraction caused by different types of source, and of the degree of attraction resulting from different combinations of general and local lighting. Some preliminary work on these lines has already been published.

Lighting should really be considered in three stages, each of which is closely linked and which should not be separated in the mind of the engineer. First, lighting should give good *visual efficiency*. That, of course, is the work with which both our Illuminating Enigeering Societies have been concerned ever since their inception. Second, lighting should give *visual comfort*. This is a matter which has followed on rather later, but which now is well documented by research both in the United States and on the other side of the Atlantic. The third requirement of good lighting may from the point of view of engineering be a little newer. This is the question of the *appropriateness* of the *character* of the lighting. To light a hospital, a school and a factory may each demand, shall we say, 20 footcandles on the working plane to achieve visual efficiency. By application of the comfort data we can achieve that level of illumination without visual discomfort, but the character of those three jobs will be entirely different. Very broadly, we know that low-level indirect lighting tends to be soporific and direct lighting with bright "spots" tends to be stimulating. Variations between extremes of that kind give a different character. There may be a possibility of formulating rules for determining the character of lighting but we have not succeeded yet in showing how to do so. This is the side of the Building Research Station work with which my colleague H. L. Gloag is most closely associated. In the case of the hospital, for example, we feel that it should not be of an institutional character, it should be homelike and at the same time should give the patient the desire to get well. At the same time it should not be so stimulating that it is a constant source of irritation to a very sick patient. A factory on the other hand should have quite a different character, it should radiate an atmosphere of efficiency and it should make the worker want to get busy and keep busy. A proper combination of lighting and color may achieve this. (Color slides were introduced to illustrate these points).

To turn to something entirely different, there is a great deal of discussion still going on in Europe about the physiological and psychological effects of fluorescent lighting. The most bitter arguments are dying down, but the embers still burst into flame occasionally. I believe you know that in 1949-50 the French education authorities banned the use of fluorescent lighting in schools, and this had considerable repercussions in other countries. In Scandinavia, especially Sweden, where almost all the new schools were furnished with fluorescent lighting, second thoughts began to prevail around 1953 and in response to pressure some careful work was done on the effects of fluorescent lighting in schools, that is to say the effect on children's vision. A comprehensive report on this survey by Dr. Hjärne gave a verdict generally favorable to the fluorescent lamp, but embodying some sound recommendations for more careful engineering. At the Building Research Station we came to very similar conclusions and embodied them in a report prepared for Government use. Floyd reported a study of a careful comparison between fluorescent and filament lighting in telephone exchanges and post office letter-sorting offices. His findings showed no disadvantages of fluorescent lighting under comparable conditions. Curiously enough, however, neither Floyd nor ourselves at Building Research Station have been able to confirm the "Kruithof diagram," the relation between acceptable minimum illumination

and color temperature. Our own studies were carefully done, but we found that even if 50 per cent of our subjects confirmed Kruithof, the other 50 per cent were either indifferent or judged in the opposite direction. We found that much more important in the judgment of the apparent amount of light was not so much the color temperature, but whether or not there were bright light sources in the field of view. Floyd found that performance under fluorescent and under filament lighting was effectively the same at quite low (10 ft-c) levels of illumination. Nevertheless I feel that if I were a lighting engineer I would not risk causing the client's dissatisfaction by installing "daylight color" fluorescent lighting at levels less than 20 ft-c. Such a precaution, of course, is of no interest to you in the U.S.A. where 20 ft-c. is a level no longer of interest.

The ultraviolet question entered into these arguments on fluorescent lighting, and the work of Latarjet in Paris was probably the most carefully done in this field. No evidence of visual harm coming to users of fluorescent lighting was established in spite of the most careful tests.

Studies were also made of the effect of fluorescent lighting on the accommodation. The work of Baumgardt, which was reported at the C.I.E. Conference in Zurich but of which I have not yet seen any further publication so far, did seem to show that work in fluorescent lighting running on a-c had a greater effect on the dimunition of the accommodation reserve than either filament lighting or fluorescent lighting on d-c. The effect was small, but linked up with the complaints which we have ourselves had at Building Research Station from middle-aged people on the borderline of presbyopia. We find that most of the people who complain about fluorescent lighting are those who probably need about half a diopter of plus correction to help them, but which they have not so far troubled to get. But when they work in fluorescent lighting it suddenly appears to them that they need it. That, of course, is nothing serious at all—everyone when he gets to a certain age needs a certain plus-correction. But it does seem to alarm some people. To them it is the crossing of the boundary between not needing to wear spectacles and then having to wear them, and this arouses concern. Weston takes this very philosophically, his wide experience extending over very many years leads him to believe that most of thse complaints clearly stem from a mild degree of neurosis. Fincham used his Coincidence Optometer technique to study the accommodation performance of eyes under fluorescent lighting, and detected no significant effect. If there had been a fluctuation of the accommodation due to the discontinuity of the spectrum of the fluorescent source, this should have shown up in the Coincidence Optometer, in which changes of 0.1 diopter can be detected. So the explanation of Baumgardt's findings, and of the causes of complaint of the near-presbyopes, must still be sought.

Flicker has continued to be a source of complaint, and in response to a request from the Building Research Board which guides our program at the Building Research Station, we undertook a study of the problem.

The new features of our work were, first, a specially designed lighting unit which enabled us to vary the frequency, the wave-form and the modulation of the light source, and hence to flicker the whole field of view, and second, the use of the multiple criterion technique which enabled us to study not only the critical fusion frequency, but also the effect of variation of frequency on visual comfort. Just perceptible flicker may not be uncomfortable — we wanted to know what conditions give rise to discomfort which would lead to complaint.

We obtained some valuable results. We were able to show that the flicker threshold was much higher than that deduced from the classical researches, which were all, or almost all, based on small fields. Where our results overlapped with those of other workers, especially Bouma and Engstrom, acceptable agreement was obtained. Perhaps the most notable result was the fact that very small differences in frequency result in large differences in sensation of flicker, a difference of only 16-20 cycles per second making the change from just perceptible to intolerable flicker. We also found a wide variation in the sensitivities of different individuals. Flicker which to one individual is barely perceptible is intolerable to another. There is here the kernel of the flicker problem. It is a minority matter, but it is serious for this small minority.

In evaluating wave-form and modulation (and hence of afterglow in a fluorescent lamp) we made good use of the Flicker Index of Eastman and Campbell, which in certain circumstances provides an adequate measure of the relative visual effect of different wave-forms. The importance of unbalance in the wave-form was demonstrated. A very small (2 per cent) 50 cycle p.s. component in a 100 cycle p.s. wave-form is readily seen as flicker, especially at high luminances (50 ft-L and above). At low luminances a much greater 50 cycle p.s. component (15 per cent) is necessary for it to be detected.

Some recent work by Ditchburn and his colleagues at Reading University on the stabilized retinal image shows promise of yielding fundamental information on the visual processes involved in the perception of intermittent illumination. Ditch-

burn's work is not yet published and I cannot anticipate its publication, but he has granted me permission to give a brief report of some of his findings.

He had already reported preliminary results using his technique of illuminating the stabilized retinal image by interrupted light of variable frequency. His more recent work shows that if the stabilized image is presented at a range of frequencies above as well as below the critical fusion frequency, the visibility of the retinal image varies with frequency in a way which suggests that two fusion mechanisms are coming into operation, the one which occurs at or about the c.f.f. and the other at a much higher frequency. These may be linked to Granit's "on-process" and "off-process" in the retinal nervous pathways. It could be argued therefore that, at frequencies well above the critical fusion frequency, intermittent light stimulation of the eye may bring into operation mechanisms which would not operate under constant light stimulation. The implications of these findings in relation to fluorescent lighting or other forms of discharge lamp lighting have not been worked out, but we can no longer be sure that intermittent light stimulation beyond the threshold of sensation is equivalent in all respects to continuous stimulation.

The critical fusion frequency is often suggested as a measure of fatigue. Brozek, Simonson and Case's work in this field is, of course, well known to you. Recently Grandjean and Bättig in Switzerland have published a study which shows that the c.f.f. is reduced significantly by mental and visual work, but not by physical work. Improvements in lighting were found to diminish the reduction in the c.f.f. the most useful improvement being the reduction of contrasts in the peripheral field. If these findings can be confirmed in other laboratories, it may be possible to establish this technique as a means of measuring objectively the value of different lighting systems. Unfortunately previous experience with such objective measures has been that they respond significantly only to large differences in the lighting. No evidence yet exists to offer any hope of achieving this desire in the near future. Weston's work on visual fatigue is already known to you from his own visit to the U.S.A. in 1953. The group at Cambridge working originally under Bartlett and now under Mackworth have devoted a great deal of study to fatigue problems. Saldanha has made investigation into visual fatigue using a technique which measures the falling-off in the accuracy of setting a vernier scale during the progress of the visual task. This technique may be sufficiently sensitive to reveal the effect of different lighting systems on the onset or holding-off of visual fatigue. But in general the situation on the systematic study of visual fatigue is at the moment not very promising, even though we know it to be of great importance. Some workers in Europe are thinking back to the work of Luckiesh and Moss on the heart-rate and muscular tension as measures of nervous effort in seeing, and resumption of work on these aspects of the problem may possibly be considered.

One tendency among some physiologists should be mentioned. This is to give to the word "fatigue" precise meanings in terms of certain physiological changes, then to demonstrate that after certain kinds of work, or in certain lighting conditions, these physiological changes do not occur, and thence to say that these kinds of work, or those lighting conditions, "do not cause fatigue." This is highly dangerous. By "fatigue" most of us include subjective as well as objective phenomena, and the word has a wide, but generally well-understood meaning. If my eyes feel tired, it is of no help to me to prove that my accommodation reserve is unchanged, or that my ocular-motor muscles are functioning without impairment, or that my electroencephalogram is normal. The search for objective measures of visual fatigue should not blind us to the fact that fatigue is not solely an objective phenomenon.

The work on visual fatigue continues, but the problem is an unsatisfying one at the moment. However, some recent results obtained by Saldanha at Cambridge and Collins at the Building Research Station give reason for slight hope, if no more. We must plod on and hope for inspiration.

This lecture is chiefly a review of work already published, but it contains some things that are new. I am grateful for the permission which I have been given to include advance descriptions of their work by Mr. Shackel, Professor Ditchburn, and Dr. Saldanha. I also acknowledge gratefully the permission of the Director of Building Research to give my lecture, and the Illuminating Engineering Research Institute for the opportunity of presenting it to you here in Cornell.

Part II of these lectures, "The Evaluation of Glare," will be published in the June 1957 issue of ILLUMINATING ENGINEERING.

Lighting Contributes to

Solving Small Store Problems

NINE AND ONE-HALF feet wide and sixty feet long — these dimensions indicate the proportions of the problems in lighting and arrangement of Jennings Jewelry Store. Mr. and Mrs. Jennings had planned the store lay ut themselves, and then called in a specialist to p vide the lighting specifications.

The lighting, it was hoped, could perform a dual function: (1) display the jewelry indoors to best advantage for merchandising, and (2) put the 115-inch store front in a competing position, for attention, with the 40- to 60-foot fronts of its chain-store neighbors.

Interior Lighting and Display

Exact dimensions in width of the interior are 9 feet 7 inches for the front section and, for the rear section, 9 feet 1 inch. Height of the ceiling is 9 feet 6 inches.

To create the illusion of higher ceiling height and of additional width to the store, continuous coves run the length of both sides. These consist of two-lamp rapid-start channels, mounted in a custom cove 18 inches below the ceiling. Forty 40-watt T-12 48-inch standard warm white lamps provide general illumination averaging 65 footcandles.

Direct incandescent light, most desirable for the display of jewelry, is provided by 200-watt, medium distribution, mirrored glass reflectors with concentric louvers, recessed three feet on center over the counters. The inner edge of the reflector units is over the outer edge of the counter, so the customer does not see reflections of the fixture in the top of the showcase. Each of these units is equipped with a 200-watt A-25 medium base, clear general service lamp with adaptor. An average of 100 footcandles is provided on counter tops.

The same type recessed reflectors are recessed on

This installation won second prize in the Philadelphia Section's 1956 contest for My Most Interesting Lighting Job. George C. Linthicum, Lighting Applications Section, Philadelphia Electric Co., provided the lighting specifications for this Norristown, Pa., jewelry store.

Frontage of 9½ feet of Jennings Jewelry, which competes with 60-foot neighboring fronts.

4- by 4-foot centers over the service and watch repairing section in the rear, providing 75 footcandles for this task.

Completing the overhead lighting, two modern decorative fixtures are surface-mounted on the ceiling, mainly for the purpose of night lighting. Each contains twelve 7-watt C-7 candelabra base, clear incandescent lamps, and their modern design and sparkle add to the appearance of the store interior. These units have been in continual operation for approximately 3450 burning hours.

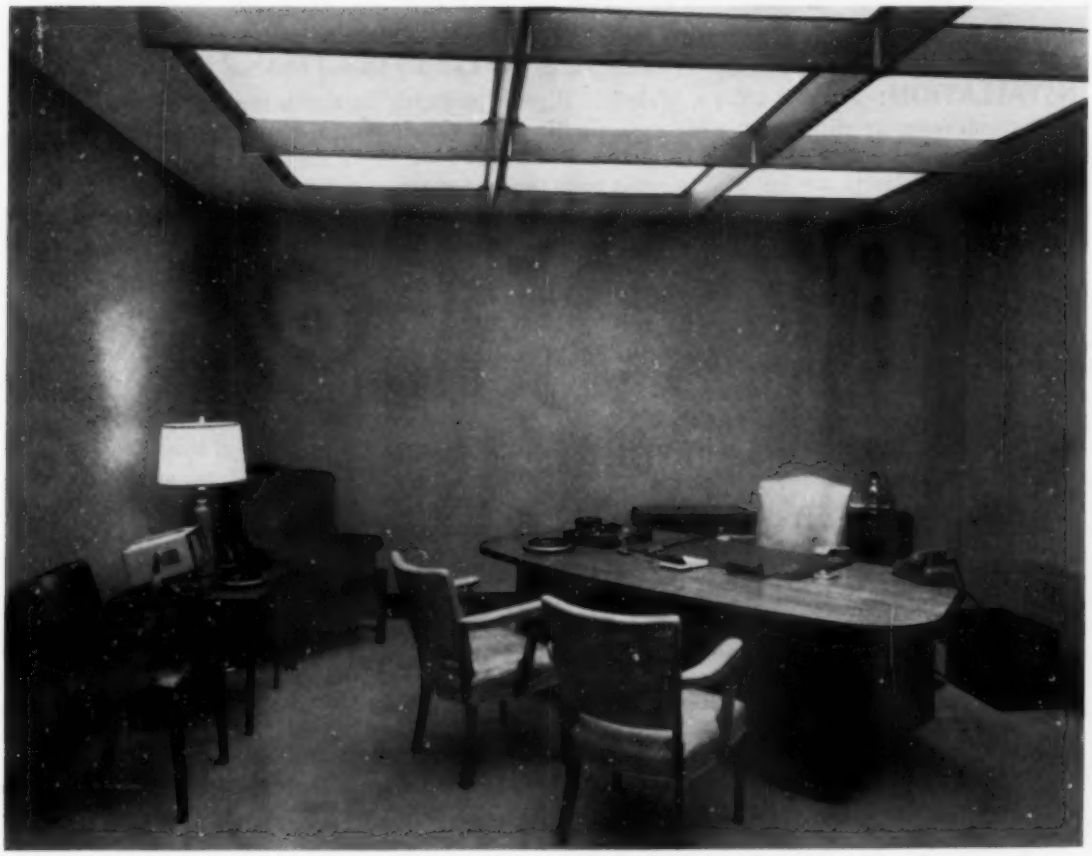
For display of silver and larger merchandise, two modernistic custom-built wall cases, 10 feet long by 5 feet high, are individually illuminated from the top with slimline strip units containing 40-watt T-12, 48-inch medium bipin standard warm white fluorescent lamps. To compensate for the 6-inch difference in store width between front and rear sections, shelf width in the foreground case is 18 inches, and 12 inches in the rear case. Five all-glass display cases, each 6 feet long by 15 inches wide, for counter-top display, use two-lamp 20-watt T-8 showcase strips with reflectors.

Flexibility in switching makes it possible to obtain various lighting levels and enables Mr. Jennings to create the effects he desires. Color scheme for the interior is: white acoustical tile ceiling, pink upper walls, walnut cases and paneling, and gray wall-to-wall carpeting. Potted plants in decorative holders, underneath the cove, add a green touch. Other environmental features are F-M music, softly transmitted from two hi-fi speakers recessed in the ceiling, and a three-ton air-conditioning unit.

Store Front and Exterior Display

To give the narrow store front additional display window area, the entrance is extended back into the building 12 feet. This furnishes a show window 13 feet long, 2½ feet wide and 4 feet high. Ten 200-watt asymmetric mirrored glass reflectors with eccentric louvers are recessed in the front of the window. These units are mounted on 15-inch centers and are equipped with 200-watt A-25 medium-base inside frosted lamps. Illumination level of 250 footcandles is provided. A 4- by 4-foot plate glass mirror installed on the wall opposite the window reflects the display to attract people walking in the "wrong" direction. A small wall-mounted case on this side is illuminated from above with a 48-inch 40-watt single lamp channel. Beyond it, another display window protrudes through the entrance back into the store. Three 150-watt R-40 spots supply punch lighting for this case.

The 6-foot-wide flagstone areaway, created by the recessed entrance, is lighted by four louvered downlights equipped with 150-watt R-40 reflector flood lamps. The all-glass entrance increases the attractiveness of the store front, by adding the lure of the interior to that of the show window area.



INSTALLATION AT PHILADELPHIA ELECTRIC CO., 211 SOUTH BROAD ST., PHILADELPHIA, PA.

Lighting an Executive Office

LIGHTING OBJECTIVE: To provide several levels of comfortable illumination for the many tasks carried on in an executive office.

GENERAL INFORMATION: This is the office of the vice president in charge of sales for an electric utility. Flexibility of lighting is required for the variety of tasks carried on in such an office — ranging from informal interviews to business conferences, to reading long reports and fine print. The office measures 21 by 16½ feet. Height to the structural ceiling is 10½ feet. The room is decorated as follows:

ceiling border	white	80% RF
plenum above plastic	white	80% RF
walls	green	40% RF
floor	beige carpet	27% RF
desk	sandalwood	12% RF
chairs	tan	17% RF
	brown	8% RF

(over)

INSTALLATION: For this office a Wakefield Sigma "packaged" luminous ceiling was chosen. This comes complete with lighting channels, plastic and sound baffles. Each section is 4 feet square. Plenum depth above plastic is 18 inches. Fourteen 96-inch T-12 standard warm white slimline fluorescent lamps are installed in seven rows two feet apart.

The lamps can be switched to give three illumination levels. After 2000 hours use the illumination levels were 100, 65 and 40 footcandles. With all lamps operating brightnesses were as follows:

walls	12 ft-L	light chairs	15 ft-L
floor	19 ft-L	ceiling border	5 ft-L
desk top	12 ft-L	acoustical baffles	70 ft-L
dark chairs	3 ft-L	luminous ceiling	215 ft-L

Lighting designed by C. W. Rudolph, Philadelphia Electric Co., 211 South Broad St., Philadelphia, Pa.

Lighting data submitted by George T. Anderson, Jr., Philadelphia Electric Co., as an illustration of good lighting practice and to aid in the design of similar installations.

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Factors To Be Considered in the Design Of High Output Fluorescent Lamps

By JOHN F. WAYMOUTH
FRANCIS BITTER
ERWIN F. LOWRY

Some problems involved in the design of very high output fluorescent lamps are discussed. The decline of efficiency of a fluorescent lamp with increasing power input is due to increasing mercury vapor pressure, and to the fact that, at constant mercury vapor pressure, there is a fundamental "ceiling" to the light output. The factors influencing this ceiling are discussed, and it is shown that the use of neon as a filling gas results in a higher ceiling and also in higher efficiency at high power inputs than the use of argon. A simple means of providing the correct mercury vapor pressure is described.

THE DESIRABILITY of obtaining ever increasing levels of artificial illumination, both indoors and out, at reasonable cost, had led to the necessity of obtaining more and more light from the individual light sources. In terms of fluorescent lighting, this results in a demand for lamps capable of producing substantially greater light output per unit length without appreciable loss of efficiency. It is desirable at the same time to be able to employ bulbs of conventional diameter and cross-section. Some of the problems involved in meeting this demand, together with their solutions, are outlined in this paper; the application of these solutions to the design of a specific lamp is discussed in the companion paper by Gungle, Waymouth and Homer.

Statement of the Problem

The problem is basically two-fold: first of all, if the power input to a fluorescent lamp is raised beyond conventional levels, the temperature of the bulb wall is increased above 40-45° C. The pressure of mercury vapor is therefore increased past the 6-10 microns appropriate to maximum efficiency of generation of ultraviolet light. Consequently, the efficiency decreases. Secondly, even if the mercury vapor pressure is maintained at the desired pressure of about 6-10 microns by artificial means, the efficiency of the lamp still decreases with increasing current and power input, as was recently demonstrated in our laboratories by C. W. Jerome.[1] A prior discussion of these matters is given by Lowry, Gungle and Jerome in their paper on high output fluorescent lamps.[2] Other data also showing these effects were given by Forsythe and Adams.[3]

Theory of Production of Ultraviolet Radiation in the Discharge

It has been shown[4] that phosphors in common use in fluorescent lamps produce light in amounts proportional to the ultraviolet irradiation up to irradiation densities many times those encountered in conventional lamps. The problem of producing higher light output then becomes that of producing more ultraviolet radiation.

As part of our program for improving fluorescent lamps, an analysis of the fundamental physical factors governing the mercury-rare-gas discharge was undertaken. The results of this study[5] have provided us with new insight into the problems mentioned above; it is these observations that we wish to discuss in some detail in this paper. In this analysis, we have considered the interactions between a "hot" electron gas and a low pressure-low temperature mixture of mercury vapor and one of the rare gases. We find that the electron "temperature" is one of the most important parameters entering into the mechanism of u-v generation. We shall not endeavor to present the details of the theory in this paper, but will confine our attention to the fundamental physical reasons for this importance.

In the field of gas discharges, the concept of electron temperature is one of the most useful as well as one of the most difficult to understand. In brief, electrons have high velocities because they are accel-

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 17-21, 1956, Boston, Mass. AUTHORS: Messrs. Waymouth and Lowry, Sylvania Electric Products Inc., Salem, Mass.; Mr. Bitter, Massachusetts Institute of Technology, Cambridge, Mass. Work done at the Research Laboratories of Sylvania Electric Products Inc., Salem, Mass.

erated by the potential drop along the discharge. They can be said to have a "temperature" because they exchange energy efficiently amongst themselves and have a Maxwellian distribution of velocities. The temperature corresponding to this distribution is a measure of the average energy of the electrons. It is the thermodynamic temperature the electrons would have to have if they acquired their energy thermally instead of from an electric field. In typical fluorescent lamps this temperature is about 11,000° K.

It is perhaps proper to ask how there can be an electron gas at 11,000° K inside a glass tube containing a gas at a temperature of some 40° C or so. The answer lies in the fact that the small mass of the electron makes it impossible for an electron to give up an appreciable fraction of its kinetic energy in an elastic collision with a gas atom. The electron gas, which gains energy from the electric field, can have a very high average energy, and still be unable to transfer enough kinetic energy to the rare gas atoms to raise their average energy (or temperature) much above room temperature.

The ultraviolet radiation which is produced in the plasma of a fluorescent lamp results from the interaction of this high temperature electron gas and a low-pressure gas of mercury vapor. The electron temperature determines what fraction of the electrons has sufficient energy to excite mercury atoms from the lowest energy state into excited states from which they can radiate energy, principally 2537A resonance radiation. At very low concentrations of electrons and mercury atoms (low power input, low mercury vapor pressure), the amount of 2537A radiation produced is proportional to the density of electrons and to the density of mercury atoms.

If the mercury vapor pressure is increased and the current density and electron concentration are kept constant, the ultraviolet output increases and goes through a maximum at a pressure of about 6-10 microns, above which it declines. The reason for this behavior is a phenomenon known as "imprisonment of resonance radiation." The ultraviolet radiation produced in the center of the discharge cannot reach the wall directly, but is repeatedly absorbed by mercury atoms and re-emitted on its way to the walls. Each time a resonance photon is absorbed, there is a finite probability that the excited mercury atom so produced will lose its energy in other ways that by re-radiation. The more times a photon is absorbed and re-emitted in travelling from the center of the discharge to the walls, the greater will be this probability. The greater the mercury vapor pressure, the more mercury atoms

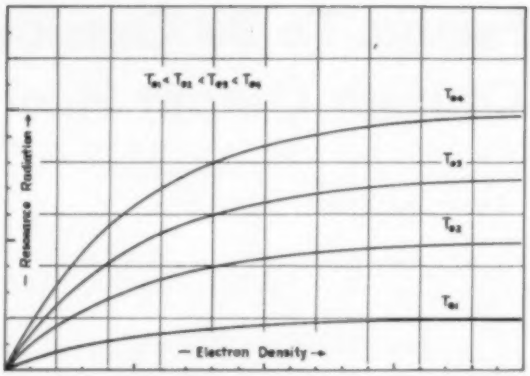


Figure 1. Schematic representation of the variation of the output of resonance radiation with electron density. Electron temperature is the parameter, all other factors assumed constant.

are present to absorb the resonance radiation, and the greater will be the losses due to this cause.

If, on the other hand, the mercury vapor pressure is maintained at its optimum value and the electron density increased by increasing the power input, the amount of 2537A resonance radiation produced approaches a "saturation" value which is independent of electron density. The reason for this is that electrons can de-excite excited mercury atoms as well as excite mercury atoms in the ground state. Such collisions are called "collisions of the second kind."

The time elapsed between an electron collision exciting a mercury atom and an electron collision de-exciting it decreases with increasing electron density. When this time is long in comparison to the mean time required for the excited atom to lose its energy by radiation, the amount of radiation output is proportional to the number of exciting collisions, or to the electron density. When this time is short in comparison to the mean time required for the excited atom to radiate, the density of excited atoms and the radiation output become independent of electron density. In this condition, the excited states of the mercury atoms are said to be in thermal equilibrium with the electron gas. Thermodynamically, it can be shown that the density of excited atoms depends only on the average energy of the electrons or the electron "temperature," provided that the electrons have a Maxwellian distribution of velocities.

This behavior is indicated schematically in Fig. 1, in which are shown idealized curves for u-v radiation versus electron density for several different electron temperatures. The actual behavior in a lamp is much more complicated than this because the electron density is not uniform in the discharge,

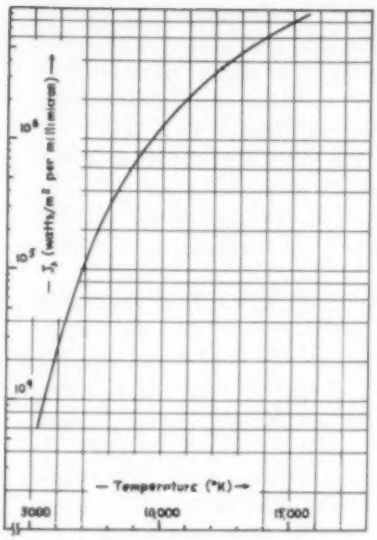
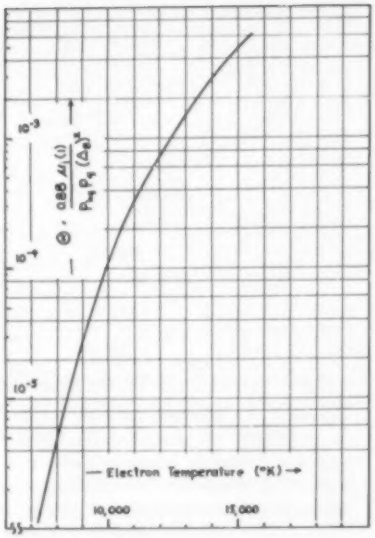


Figure 2. (left) Spectral emittance as a function of temperature, computed from Planck's Law at 253.7 millimicrons. The effective line width of the resonance line radiated from fluorescent lamps has been estimated[6] to be approximately 2×10^{-3} mμ.

Figure 3. (right) Electron temperature versus a dimensionless H; μ_1 (1) is the mobility of mercury ions in the filling gas at one millimeter pressure, P_g is the pressure of the filling gas in millimeters, P_{Hg} is the pressure of mercury vapor in microns, and Δ_8 is the tube diameter in eighths of an inch.



but has a maximum value at the axis and decreases to relatively small values at the walls. Therefore the density of excited atoms will reach equilibrium in the center of the lamp long before it does near the outer surface.

If the electron density were uniform, and the density of excited mercury atoms were the equilibrium density, right up to the walls of the tube, then the resonance radiation power output could be computed from Planck's thermal radiation formula in which the temperature to be used is the electron temperature.[6] Owing to the fact that radiation and matter are not really in thermal equilibrium in a plasma, the observed saturation value for ultraviolet output falls below this value computed from Planck's Law in particular lamps which have been investigated by 50 per cent to 75 per cent. Fig. 2 shows the spectral emittance as a function of temperature at 2537A, as computed from *Planck's Law*.

The situation may be considered as analogous in some respects to that which is observed in the radiation from a tungsten filament. Fundamentally, the radiation per unit area of a tungsten filament depends only on the temperature of that surface; to get more radiation, increase the temperature. In the "saturation" range of u-v output from the mercury-rare-gas discharge, the same is also true. To get more radiation out, it is necessary to increase the *electron temperature*.

There is an important difference, however; the temperature of any incandescent filament now known cannot be increased past 3655° K, the melting point of tungsten. The temperature of importance in a fluorescent lamp is the electron temperature, which in conventional lamps is already about 11,000° K. It can be increased several thousand degrees, by means which we shall describe.

It has been shown that in the "saturation range," the ultraviolet output becomes independent of electron density. All other electron energy losses remain approximately proportional to the electron density, however. Consequently, the nearer to saturation the lamp is driven, the less efficient it becomes. This, then, is the fundamental reason for the decline in efficiency with increasing power input. It is evident, therefore, that if high light output is to be obtained at high efficiency from a fluorescent lamp, it is necessary to have the electron temperature as high as possible, in order to have the "ceiling" to the light output as high as possible.

The factors which determine the electron temperature have been described in a previous publication.[5] The relevant equations are too complicated to review in detail in this report. A partial summary of results obtained is shown in Fig. 3, in which is plotted a quantity H as a function of electron temperature. This curve is applicable only to the condition of equilibrium between electrons and excited mercury atoms which is obtained at very high electron densities. Among other factors influencing it, H is proportional to the mobility of mercury ions in the rare gas used. An increase in H results in an increase in electron temperature, so that an increase in the mercury-ion mobility will increase the electron temperature.

The mobility of mercury ions is largest in helium, and decreases with increasing mass through neon, argon, krypton and xenon. One way to increase the electron temperature, therefore, is to use neon or helium for a filling gas instead of the usual argon or krypton. According to the ideas which have been

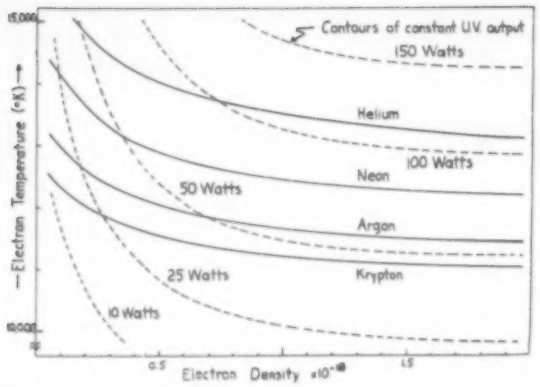


Figure 4. A contour plot of u-v positive column watts as functions of the electron temperature and density, and the relations between these two variables in a 48-inch T-12 lamp at one millimeter gas pressure and 6 microns of mercury vapor pressure according to the theory described elsewhere.[5]

outlined, this should make it possible to reach higher light output than could ever be obtained from a conventional argon-filled lamp. It should also make it possible to obtain high light output at substantially higher efficiency than with a conventional argon-filled lamp, provided that the increased losses due to elastic collisions between electrons and gas atoms do not counterbalance the gain due to the increased saturation value of the light output. Previous efforts to improve lamp performance through the use of different fill gases have been directed toward reducing these losses by using a heavier rare gas, krypton, for instance.[7] We find that the effects of the rare gases on electron temperature are of greater importance at high power input.

Similar conclusions are reached if a more rigorous analysis is undertaken, in which thermal equilibrium between electrons and radiation is not assumed. This has also been done and some of the theoretical results obtained are summarized in Fig. 4, for 48-inch T-12 bulbs at six microns mercury vapor pressure.

For a given mercury vapor pressure and bulb size, the ultraviolet output is a function of electron density and electron temperature. This could be represented by means of a three-dimensional plot, but, for ease of presentation, the contours of constant u-v output on the three-dimensional surface are plotted in Fig. 4 as dotted lines. Once electron temperature and electron density are known, the ultraviolet power output from the 48-inch T-12 bulb can be determined by interpolation.

The electron density and electron temperature are also related, as are shown by the solid heavy curves. At low power inputs and electron densities, the electron temperature decreases rapidly with increasing electron density, as is shown by the curve for argon, for example. At higher electron densities the electron temperature approaches a value independent of electron density. It is shown that the lighter the fill gas, the higher the electron temperature. The curves drawn are for one millimeter pressure of fill gas; increasing the gas pressure lowers all the curves, maintaining their relative positions.

To compute the ultraviolet output from these curves for the 48-inch T-12 bulb, knowledge of the electron density and the nature of the filling gas is needed. The curve of electron temperature versus electron density for helium, for example, crosses the contour of 100 watts u-v output while that for argon crosses only the 50-watt contour. The saturation level of u-v output for helium and neon is seen to be higher than that for argon and krypton.

These curves are very useful to illustrate the dependence of total ultraviolet output on these factors, but they tell nothing about efficiency. The ultimate efficiency of generation of ultraviolet radiation in lamps depends also on the various other energy losses of the electrons such as elastic collisions with gas atoms and other radiation losses, for instance. These matters are discussed in the next section.

Application

Fig. 5 shows curves of light output versus power input at fixed mercury vapor pressure for 48-inch T-12 bulbs filled with two millimeters of neon, argon, krypton and xenon. For any given curve, the electron density is approximately proportional to power input, although the constant of proportionality is different for each. The formal similarity between these curves and those of Fig. 1 is readily

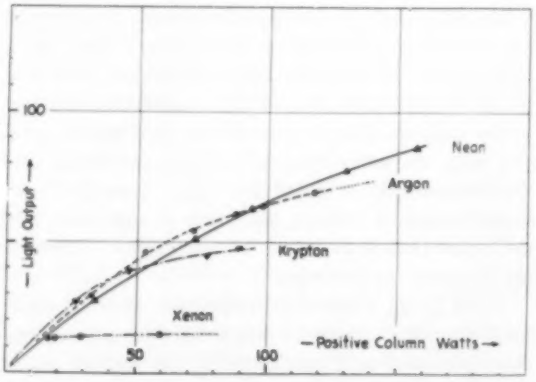


Figure 5. Light output versus power input for 48-inch T-12 lamps filled at two millimeters pressure with the various rare gases.

apparent. For positive column power inputs greater than 95 watts, the neon-filled lamp produces more light than the argon-filled lamp. Of particular interest also is the fact that the saturation values of the light output increase monotonically as the fill gas is varied from xenon through krypton and argon to neon. This variation is in qualitative agreement with that shown by Fig. 4.

As regards the efficiency, the data shown in Fig. 5 is re-plotted in Fig. 6, where light output per watt is presented as a function of positive column watts in a 48-inch T-12 lamp. From this, it is clear that efficiency declines much more rapidly with increasing power input for krypton than for argon, and more rapidly for argon than for neon. This qualitative behavior has been observed in a variety of different tube sizes.

The *absolute values* of the wattages in lamps at which a lighter gas becomes more efficient than a heavier are dependent upon gas pressure and bulb dimensions. The dependence on gas pressure occurs because the variation of efficiency with pressure is slightly different in each of the gases, while the dependence on bulb dimensions arises because of the different positive column gradient in each of the gases. This makes the electrode voltage drop a different fraction of the total voltage drop of lamps of the same size filled with the various gases.

Mercury Vapor Pressure

It was pointed out that these curves were taken at fixed mercury vapor pressure of six to ten microns, at which maximum efficiency is found. In a conventional fluorescent lamp this mercury pressure is obtained by operating the lamp at such a power input that under normal ambient conditions the temperature of the bulb-wall is 40-45° C. When lamps are operated at power inputs greatly in excess of normal values, the temperature of the bulb wall exceeds the 40-45° C by a considerable margin, and the vapor pressure of mercury in equilibrium with the bulb walls is much larger than the optimum six-to-ten micron range.

We have found that, in order to maintain a 6-10 micron mercury vapor pressure, it is not necessary that the temperature of the whole lamp be at 40-45° C, but merely that the temperature of a small cool spot be 40-45° C. All the excess mercury in the lamp then condenses at that spot and the vapor pressure of mercury in the lamp becomes that corresponding to the temperature of the coolest spot. It is surprising that this should be true even in the presence of inert gas at much higher pressure and in a long tube, because the diffusion of mercury vapor is slow under such circumstances. Nonetheless, we have found that maintaining an area far less than *one per cent* of the lamp's total surface area at the desired temperature will maintain the desired mercury vapor pressure even when all the rest of the lamp surface is at 80° C or hotter. The ends of the lamp often are suitable for the cool spot. The use of a cool spot as described in greater detail in the companion paper, is very important not only to the efficient operation of lamps at high power loading, but of normal lamps which run too hot for other reasons, such as a high ambient temperature or inadequate circulation.

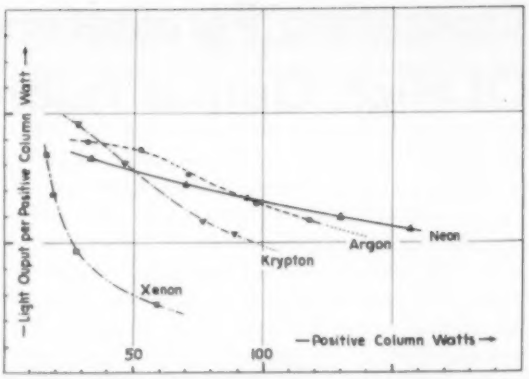


Figure 6. Light output per watt as a function of positive column power input for 48-inch T-12 lamps filled at two millimeters pressure with various rare gases.

Summary

We have demonstrated that it is possible to obtain substantially higher light output per unit length of a fluorescent lamp. Despite the length of the tube and the presence of inert gas, the effect of high mercury vapor pressure usually associated with high bulb-wall temperatures can be overcome by providing a small "cool spot" in the lamp. The loss in efficiency associated with increased power input can be considerably minimized by the use of neon as a filling gas instead of argon or krypton. In the companion paper, the application of these ideas to the design of high output fluorescent lamps will be considered.

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[*Discussion of this and the following paper begins on page 267.*]

Operating Parameters Of High Output Fluorescent Lamps

By W. CALVIN GUNGLE
JOHN F. WAYMOUTH
HORACE H. HOMER

Compared to incandescent lamps and to most other artificial light sources such as the high intensity mercury arc or even to the venerable Welsbach mantle, the fluorescent lamp is inherently a low brightness source. For many, and indeed for the majority of lighting applications, this is highly desirable and is one of the properties of the fluorescent lamp which is responsible for its tremendous popularity.

There are many important applications, however, where low brightness of the source is a distinct liability. For high bay industrial lighting, for luminous ceilings and for street lighting, higher luminous intensities than those normally furnished by present day fluorescent lamps are much to be desired.

Recognition of this liability has led to work in our laboratories directed toward understanding the fundamental physical reasons for the relatively low ceilings on the light output of fluorescent lamps. This study, which has been in progress for the past several years, has led to the discovery that one of the most important factors influencing the production of ultraviolet radiation by the mercury-rare-gas discharge is the average energy of the electrons carrying the discharge current. As discussed in the paper by Waymouth, Bitter and Lowry,[1] it was also found that the electron energy, or electron temperature, can be substantially increased by the use of neon as a filling gas instead of argon or krypton. Because of the high electron temperature, lamps with neon fill gas have greater efficiency at high power input than do lamps filled with argon or krypton.

The further discovery that mercury vapor pressure in a heavily-loaded lamp can be maintained at about 6-10 microns, simply by providing one cool spot at 40° C on the lamp, made it possible to develop a new line of high output lamps yielding much greater light output per foot of length than any existing fluorescent lamp. These lamps will be referred to in this paper as VHO lamps; the initials stand for their most salient characteristic: Very High Output of light. Table I shows light output per foot and efficiencies of various types of white fluorescent lamps, for the purposes of comparison.

TABLE I.

Lamp	Light output per foot (Lumens) (100 hour)	Efficiency (lpw)
96T8 cold cathode	280	54
96T12 slimline	660	72
96T12 100-watt R. S.	930	74
96T12 200-watt VHO	1630	65

Attention is especially called to the fact that the 1630 lumens per foot obtainable from the VHO lamp is *nearly double* that obtainable from the 96T12 100-watt Rapid Start and *two and one-half* times the light output obtained from the 96T12 slimline. The purpose of this paper is to describe the application of these principles, mercury vapor pressure control, and the use of neon, to the development of this lamp.

Gas Filling

As discussed in the companion paper, at high power inputs, the use of neon as a fill gas gives greater efficiency than argon or krypton. An additional point to be considered involves the electrical characteristics of lamps filled with these gases. Table II gives these electrical characteristics for 48-inch T12 lamps filled with 2.0 mm of the various

TABLE II — Electrical Data for 48-inch T-12 lamps operating at 100 watts and having controlled mercury vapor pressure-gas fill pressure 2.0 mm.

Fill Gas	Current	Voltage
Helium	0.4 amp	315
Neon	1.31	99
Argon	1.90	60
Krypton	2.65	39
Xenon	3.60	35

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rare gases, operated at 100 watts. We wish to make a particular point of the fact that the neon fill gas results in a lower current and higher voltage at 100 watts than does argon. This means that a simpler electrode structure can be used.

Some additional data are shown in Table III, giving a comparison of the various characteristics of 96T12 lamps filled with neon and argon to 1.0 mm pressure operating at 200 watts. The mercury vapor pressure in these lamps was maintained in the range of 6-10 microns.

TABLE III.

Fill Gas & Pressure	Amperes	Volts	Lumens	lpw
	(Controlled Hg Vapor Pressure)			
1.0 mm Neon	1.30	180	14000	70
1.0 mm Argon	2.20	102	9900	50
	(Uncontrolled Hg Vapor Pressure)			
2.0 mm Argon (96T12 Rapid Start)	2.30	97	8000	40

The characteristics of a 2.0 mm argon 96T12 rapid-start lamp operating at 200 watts are also given. The mercury vapor pressure in this lamp was controlled by the bulb wall temperature only and is probably of the order of 100 microns. These data were obtained on new lamps after two hours burning to stabilize the electrical and optical characteristics.

Mercury Vapor Pressure

The most efficient operation of fluorescent lamps is obtained at a mercury vapor pressure of about six to ten microns, which is the vapor pressure of mercury between 40 and 45° C. The temperature of the bulb-wall in these heavily loaded lamps is very much higher than this, but proper vapor pressure can be obtained by cooling a very small fraction of the bulb surface to 40° C. In a short time, all excess mercury in the lamp condenses upon this, the coolest spot, and the vapor pressure in the lamp becomes that corresponding to its temperature of 40° C.

We have found two effective means of cooling a given area of a lamp. These are: (1) increasing the rate of heat dissipation from a given spot by means of metallic or heat-conducting contacts to the bulb which can remove heat at a faster rate than air convection; and (2) decreasing the rate of heat flow to a specific area from inside the bulb to the point where air convection will cool it to the proper temperature. Methods tried in the former category have included various types of radiating fins clamped or cemented to the lamp, in such a way that the area of contact between fin and bulb was at 40° C. A single point contact between a ½-inch aluminum rod and the T12 bulb lowered the temperature of the condensed mercury to 40° C. Methods in which the heat conducting contacts were an integral part of the fixture have also been found to be very satisfactory. A particular advantage to these last is the ease with which thermostatic control may be built into the heat conducing contacts, so that lamps may operate at maximum efficiency over a wide range of ambient temperatures.

The second method of reducing the temperatures of the cool spot has the very definite advantage that no additional external apparatus is required. Except for the necessary ballast, the lamp is self-contained. For that reason, this method has been adopted for use in VHO lamps. We have found that the ends of the lamp are a very satisfactory place for the cool spot, and that by suitable design of the lamp mount the ends can be caused to operate at the desired temperature of 40° C in the rated ambient of 25° C.

The particular design employed in the VHO lamp types is a circular metallic reflecting shield or shields mounted between the electrodes and the lamp ends. The purpose of these shields is to prevent radiation from the heated filaments striking the bulb near the base, and to break up convection currents in the heated gas about the filaments so they do not carry heat to the ends of the lamp. This gives in effect a small cool spot at the bulb end.

Some temperature data are presented in Table IV for a single shield mount as a function of the distance from the end of the bulb, for operation at 25 watts per foot. A drawing of this mount structure is shown in Fig. 1. The dimension x shown in the figure corresponds to the dimension x in the table. The distance between the shield and the filament was maintained constant at 10 mm for data presented in the table. The temperatures given in the table were measured at a point one or two millimeters away from the base with the lamp burning horizontally in still air at 25° C.

TABLE IV.

Distance x (mm)	End Temperature (°C)
10	43.0
14	40.0
18	38.2

A photograph is presented in Fig. 2 of the end of a VHO lamp. The end of the bulb was made without phosphor coating so the condensation of mercury after a short burning period is clearly visible.

Stabilization of Lamp

Upon initiating a discharge in a fluorescent lamp the light output and electrical characteristics of the device are not constant. A first they change rapidly

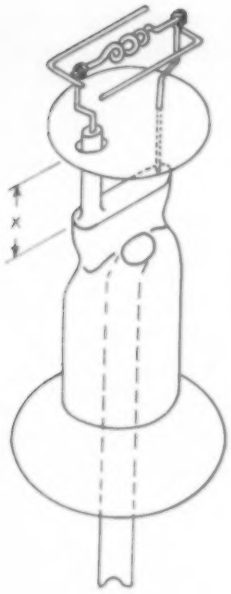

Figure 1. (left) Drawing of mount structure for a 25-watt per foot VHO lamp.

Figure 2. (right) Photograph of end of a 25-watt per foot VHO lamp showing condensed mercury.

and then approach an equilibrium value. These changes are the result of changes in the lamp's mercury vapor pressure as the lamp's temperature changes from its equilibrium value when not lighted to its equilibrium value when lighted. All fluorescent lamps exhibit such a behavior, and the term "stabilization period" is given to this period of changing lamp characteristics. (Specifications call for a minimum stabilization period of at least 10 minutes for all photometry and electrical measurements).

For the VHO series of lamps the stabilization period is somewhat longer and the fluctuations of the various lamp characteristics are quite revealing. In Fig. 3 curves are presented showing light output, voltage and current during the period of stabilization for a "green" lamp maintained at constant power.

Initially, droplets of mercury are distributed haphazardly throughout the lamp. When the lamp is lighted, the bulb wall temperature increases towards its equilibrium value of 85-90° C. The mercury vapor pressure increases correspondingly, and very shortly exceeds the 6-10 microns for maximum efficiency of generation of 2537 radiation, resulting in a decreasing amount of emitted light. With increased mercury vapor pressure, the effective resistance of the lamp decreases, resulting in an increasing current and decreasing voltage drop as constant wattage is maintained. Since the lamp is designed to have an end temperature of about 40° C, mercury vapor diffuses through the inert gas to the ends of the lamp and condenses.

Upon evaporation of all droplets of mercury in the vicinity of the arc stream and their condensation at the ends of the lamp, the vapor pressure throughout the lamp will be determined by the temperature of that chamber, which is the coolest part of the lamp, despite the long tube and the presence of an inert gas. At this point in the stabilization period, the emitted light is increasing as the

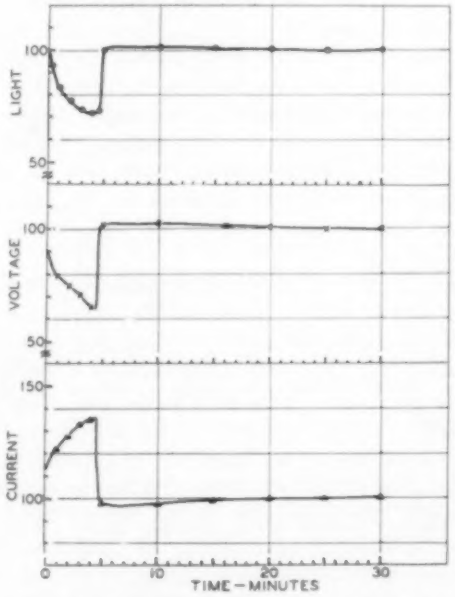

Figure 3. Light and electrical characteristics of a VHO lamp operating at constant wattage during period of stabilization.

vapor pressure approaches the value of 6-10 microns. In addition, the effective resistance of the discharge increases, resulting in a lower lamp current and higher voltage drop. The electrical characteristics of the lamp are quite valuable in determining when stabilization is complete, and the condensed mercury temperature is correct.

The length of the period of stabilization is determined primarily by four factors. These are:

(1) Quantity and distribution of mercury in the lamp.

(2) Temperature difference between the discharge region and end section.

(3) Power input into the lamp, including that dissipated in the filaments.

(4) Pressure of fill gas.

The first factor determines the amount of mercury to be transported to the lamp cool spot or chamber and the distance of transportation. The second and third factors determine the pressure differential between the discharge region and the ends of the lamp. These two factors in conjunction with factor four determine the rate of diffusion of mercury. Depending upon these factors the time of stabilization can vary from 15 minutes to a few hours.

If stabilization is carried out on a fixed ballast at constant input voltage, the behavior is qualitatively the same as with constant power with the exception that the current is essentially constant. The curves of electrical characteristics and light during the period of stabilization for two lamps in series operating on a fixed ballast are shown in Fig. 4. In general, the two lamps do not stabilize in the same length of time, due mainly to factor (1) above.

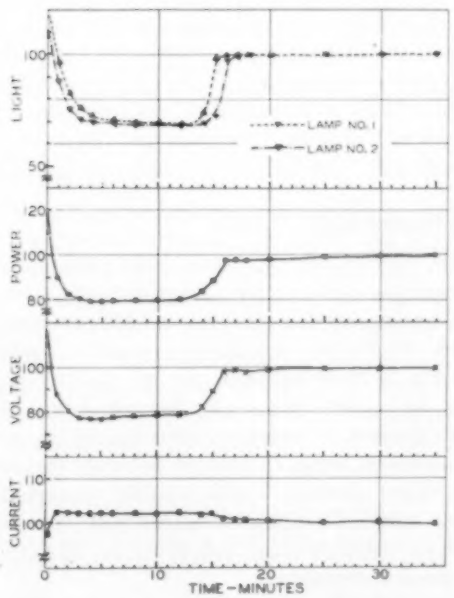

Figure 4. Light and electrical characteristics of a VHO lamp operating on a constant-current ballast during period of stabilization.

In comparing Figs. 3 and 4 it will be noticed the time of stabilization is considerably shorter for a constant wattage type ballast. This would be expected since lamp power is a controlling factor for stabilization (see above factor 3). With this advantage of shorter stabilization time for a constant wattage ype ballast it should be noticed that during the time of stabilization the lamp current can reach a value of 135 per cent of its equilibrium value.

Once the mercury vapor has been condensed in the ends of the lamp, the variation of light output and electrical parameters upon relighting is no more pronounced than for any conventional fluorescent lamp. However, mechanical abuse of the stabilized lamp can result in mercury droplets being thrown into the body of the lamp and will necessitate re-stabilization of the lamp.

Effects of Ambient Temperature

Fluorescent lamp operation is materially affected by ambient temperature conditions. The VHO type lamps are no exception. This effect on light output and efficiency for the VHO lamps is shown in Figs. 5 and 6. Curves for the 96T12 rapid start lamp are given in these figures for comparison purposes.

Fluorescent lamps are usually designed to yield maximum light output in the ambient temperature range of 70-80° F. For temperatures above and below this maximum the generated light decreases. Referring to Fig. 5, the VHO lamps yield maximum light for an ambient of 80° F. This is about 5° F higher than the maximum for the 96T12 rapid start lamp. The relative light yield of the VHO lamps for the high temperature side of this maximum is as good as for the rapid start lamp. On the low temperature side, the relative yield is significantly better.

Figure 6, which is a plot of efficiency in per cent

TABLE V — Comparative Fixture Data for 96T12 RS Lamps and VHO Lamps (96T12 200 watts).

Fixture Type	Ambient Temperature (°F)	Ratio of Light Outputs (96T12RS:VHO 96T12 200 watts)
Bare Lamp	80°	1:1.80
Louvered Trimline	100°	1:1.92
Slotted Industrial (10% upward component)	100°	1:1.86
Plastic Trimline	100°	1:1.87
ICL	100°	1:1.93

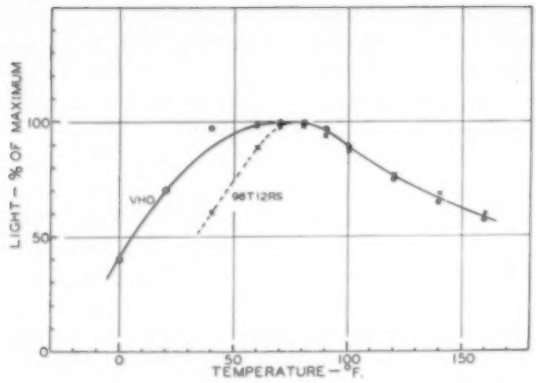

Figure 5. Variation of light with ambient temperature for VHO and 96T12 rapid-start lamps.

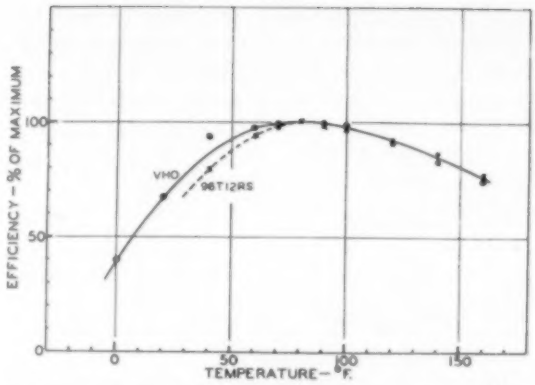

Figure 6. Variation of luminous efficiency with ambient temperature for VHO and 96T12 rapid-start lamps.

of maximum as a function of ambient temperature, shows a similar result.

The data presented in Figs. 5 and 6 were taken on bare lamps. Some 2-lamp commercial type fixture operational data are given in Table V. The fixtures were hung 3 feet below the ceiling in a room having 12-foot ceilings. The room ambient was maintained at 100° F. The data are presented as the ratio of the light from the 96T12 rapid start lamped fixture to the light from the same fixture lamped with VHO lamps (96T12 200 watts). The ratio of the light output from a bare 96T12 rapid start lamp to a bare VHO (96T12 200 watts) lamp (both operating in still air at 80° F) is 1.80, as recorded in the table.

These data agree within experimental error with the curves of Fig. 5.

It must be emphasized, however, that the ambient temperature is the temperature of the air in which the bulb is situated; therefore adequate ventilation of the fixure must be provided if satisfactory operation is to be obtained. These lamps operate at several times the light output and power level of previous lamps and correspondingly greater heating of the air in fully enclosed or troffer fixtures should be expected.

Ambient temperatures not only affect the light yield of a fluorescent lamp but also the lamp's starting voltage. Curves of this variation are given in Fig. 7. The upper curve in this figure is for 2-96T12 VHO lamps operating on a rapid-start series type circuit and the lower curve is for 2-48T12 VHO lamps operating on a rapid-start series type circuit. These curves are similar in nature to that for other rapid-start type lamps. It should be noticed that reliable starting can be obtained for 2-in-series 48T12 VHO lamps at 340 volts for ambient temperatures as low as 0° F. For 2-in-series 96T12 lamps, reliable starting at 0° F can be obtained for 560 volts. The open circuit voltage crest factor on these ballasts was 1.4.

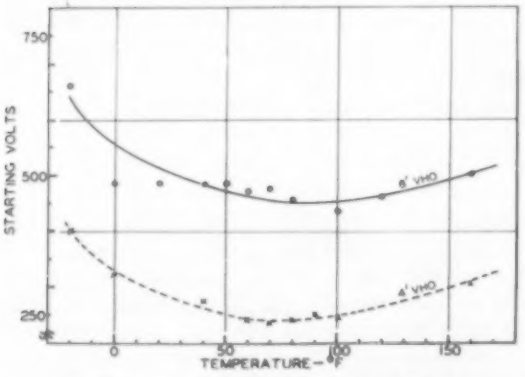

Figure 7. Variation of starting voltage with ambient temperature for 2—48T12 and 2—96T12 VHO lamps operating on rapid-start series ballast.

Still Higher Light Output

The method of controlling condensed-mercury temperature which we have described in this article has a great advantage that has not been touched on as yet. That is the fact that the cool spot temperature can be made optimum, for any desired power input, by suitable changes in electrode design. One of the greatest obstacles to increasing power input to fluorescent lamps in the past has been that mercury vapor pressure was inexorably connected to power input. That is all changed now; in effect, mercury vapor pressure and power input are now independent variables.

It is plain that the application of this development does not stop short at merely double the power input of previous fluorescent lamps. For

example, we have made lamps which operate at fifty watts per foot and give efficiencies in excess of fifty lumens per watt. Table VI shows data on light output and efficiency of 48T12 and 96T12 lamps operating at this power level. Neon is used as the fill gas; reference to the paper by Waymouth, Bitter and Lowry[1] shows that the lighter fill gas gives greatest advantage at higher power inputs.

TABLE VI.

	Power (watts)	Lumens (100 hrs.)	lpw (100 hrs.)
48T12	200	10,000	50
96T12	400	21,000	52.5

These lamps are competitive in light output and efficiency with high-pressure mercury arc lamps. They deliver more light output per unit length than any low-pressure fluorescent lamp ever made anywhere.

Summary

Using the principles which have been outlined in the paper by Waymouth, Bitter and Lowry,[1] we have shown that it is possible and practical to double and even quadruple the amount of light obtainable from a given fluorescent lamp. The achievement of these levels of light output at efficiencies comparable to conventional lamps is at odds with previous beliefs as to fluorescent lamps. With these new lighting tools, fluorescent lighting will be more attractive for street lighting and high bay lighting. For conventional fluorescent applications, a smaller number of fixtures will be required to obtain a given light level using these lamps, resulting in a reduction of initial cost and maintenance cost for the installation.

Acknowledgements

The authors wish to express their appreciation to the Product Development Group of the Sylvania Fluorescent Lamp Plant and Charles W. Jerome and Lawrence J. Moynihan, Jr., of the General Engineering Group of the Sylvania Lighting Division for their assistance in gathering data for this paper. Thanks are also due to George Spears and to the Photometry Section for assistance in making measurements of light output.

Reference

1. Waymouth, J. F., Bittner, Francis, and Lowry, E. F.: "Factors to be considered in Design of High Output Fluorescent Lamps," ILLUMINATING ENGINEERING, this issue.

(The following discussion covers both the papers by Waymouth-Butler-Lowry and Gungle-Waymouth-Homer.)

DISCUSSION

A. H. MANWARING:* It is a privilege to offer discussion on the two papers "Factors to be Considered in the Design of High Output Fluorescent Lamps" and "Operating Parameters of High Output Fluorescent Lamps." The authors of both papers are to be highly complimented on their work. Their company has brought forth, through these responsible men, the development of an outstanding fluorescent lamp.

Speaking from the standpoint of a manufacturer of outdoor fluorescent equipment, this improved light source, the VHO lamp, will undoubtedly widen the field for exterior fluorescent illumination. Fluorescent floodlighting and street lighting installations will become more acceptable with the advent of smaller and lighter luminaires which will produce illumination levels equal to or greater than those provided by existing designs.

In the field of service station lighting, there is an increasing demand for higher levels of illumination, incorporating the fluorescent lamp, on building faces. The VHO lamp in suitably designed luminaires may well supersede the current practice of using PAR lamps and incandescent floods for this service. In the lighting of large areas, fluorescent floodlights using the 48-inch or 72-inch VHO lamps will become far stronger competitively than the present incandescent and mercury vapor types of floodlight.

Bearing more directly upon the text:

(1) The decision to base the new lamp design on the T12 bulb diameter is most satisfactory. The VHO lamps may thus be used in luminaires, employing reflectors originally developed around the T12 rapid-start lamps, without further design change.

(2) In Table I, the lumen per watt efficiency of the VHO lamp is less than that of the 96T12 100-watt rapid-start lamp. It is expected that the efficiency (65 lpw) will be increased through further research. It has been noted elsewhere that the phosphors are capable of absorbing more 2537 A radiation and reradiating it as more visible light. In outdoor fluorescent floodlighting it is desirable to project a pattern of light to maximum distances. One method of doing this is to literally cram a sufficient number of lamps into a housing until the projected area of lamp brightness is sufficient to produce the required illumination. In all probability, this is done in an effort to produce higher illumination levels from an inherently low brightness source. The inefficiency of such methods is obvious. The high lpw rating of individual lamps is lost in the shuffle of high bulb wall temperatures, high percentage of trapped light, etc. As a result, the customer does not profit from the high lpw rating. Much can be done to overcome such conditions by proper usage of the brighter VHO lamps. In properly designed luminaires, the higher ratios of lumens per foot will more than offset the currently lower ratios of lumens per watt and the customer can be given more illumination where he needs it.

(3) In Item III, "Mercury Vapor Pressure," it is noted that the cool spot is fixed at the desired 40C temperature, in order to provide maximum lumen output by suitably designing the lamp mount. This applies to laboratory conditions of the bare lamp operating horizontally in still air at 25C ambient. If it will be agreed that bare lamp installations of these higher brightness lamps will be relatively rare, and that the ultimate success of a lamp design depends upon its performance in luminaires designed for and

*Philadelphia Electrical and Manufacturing Co., Philadelphia, Pa.

accepted by the public, does it not seem that the luminaire manufacturer is being unduly penalized by the loss in lamp lumen output encountered by partially or completely enclosing the lamps? It would be interesting to see the result of an experiment wherein the cool spot could be lowered in temperature (other than by increasing dimension *X* or providing some external mechanical or electro-mechanical means) to the point where the 6-10 micron mercury vapor pressure and maximum lumen output could be realized under under lamp ambient temperatures encountered in typical partially or completely enclosing luminaires.

The complications and arguments pro and con on this subject are apparent to all of us, but they are offered only as a thought, it being beyond the scope of these brief comments to discuss them further. From the standpoint of this speaker, interest would lie principally with totally enclosed luminaires. Such luminaires, as used outdoors, are usually bug-proof, dustproof and weather-tight. Adequate ventilation for satisfactory operation would provoke added costs and complications. In service station lighting alone, the volume of lamps going into totally enclosing outdoor luminaires should warrant some investigation of this temperature vs. lamp lumen output problem. The data in Table V are interesting and seem to indicate a step in the right direction.

(4) One objection to the reflecting shield in the lamp is the extent of inactive area at each end. This, of course, becomes more pronounced when luminaires are mounted end to end. Although this will become a less critical item as the public gets accustomed to seeing it, it is hoped that some remedy can be found in the near future.

(5) Another interesting problem may be to determine what happens, if anything, to mercury vapor pressure when the lamp is burned vertically or at some upward angle. Unless the cool spot at the lower end of the lamp will, alone, serve to control the pressure, additional cooling of the upper end will apparently be required.

(6) Probably due to lack of time to date, no lamp lumen maintenance data have been published. For the luminaire manufacturers to supply the customer with average illumination values, these data are most important.

(7) Item VI and Table VI suggest even better light sources to come.

M. E. ROBERTSON:* The authors of both these papers are to be congratulated for their work in preparing and presenting these very enlightening papers on a very difficult subject.

As a representative from a ballast manufacturer, I hardly feel qualified to discuss all the contents of these papers. For this reason, my remarks are directed toward the design and application of the ballasts for the VHO lamps.

The trend in fixture design using 425-milliampere lamps has been toward thinner fixtures requiring small cross-section ballasts. The result has been greater heating and noise problems, particularly for slimline lamps. In these shallow fixtures, the ballast losses have remained essentially the same, while the heating from the lamps has not changed. With the smaller channels, the volume of air surrounding the ballast has been reduced, and consequently, a heating problem exists. Fixture manufacturers have been able to solve this problem by designing fixtures which do a better job of conducting the heat away from the ballast.

This same heating-noise problem will exist, but multiplied many times, with the very new VHO lamps.

With a slimline fixture, the ballast was called upon to furnish 148 watts to two 8-foot lamps. This amounts to 18.5 lamp watts per foot of fixture, much of which goes into heat.

With the VHO lamps, the ballast must supply 400 watts to two 8-foot lamps, or 50 watts per foot of fixture. This is 2½ times the heating of the slimline lamps, and of course, the ballast losses will be higher.

From this, you can get a good idea of the acute fixture-ballast heating problem which we face with the VHO lamps. This problem will be solved by the cooperation of the fixture and ballast manufacturers, but it will not be easy.

The shape of the 400-watt ballast for the two 8-foot VHO lamps is problematical at this point. The ballast manufacturers' job will be easier, both from the heating and noise standpoints, if this new ballast has a larger cross-section than any ballast now being made. Perhaps a 4-inch square cross-section would be desirable. The fixture manufacturer, on the other hand, would like to see a ballast cross-section which would fit into existing channels. To satisfy this desire, the ballast might be in a 3⅛ by 2⅝-inch case, 25 inches long, or it might be split up into two separate cases. The choice of ballast and fixture dimensions will have a great bearing on the heating problem. Perhaps the ballast should not be mounted in the fixture at all.

The VHO lamp represents a major advancement in fluorescent lighting. Its development must have entailed the solution of problems much greater than those now facing us. It is now the responsibility of the ballast and fixture manufacturers to solve the heating problem, and to provide auxiliaries for the application of the VHO lamp.

J. O. AICHER:* We believe that operation of the fluorescent lamp under conditions of high electron temperature and optimum mercury vapor pressure is likely to be not the entire explanation for the ability to load the fluorescent lamp withort loss in efficiency. It is well known[1,2] that in sodium lamps, which are very similar, low pressure neon-filled, resonance radiation lamps, their high current loading causes the sodium vapor to concentrate in the region of the bulb wall. This results in light (resonance radiation) generation at such a point in the lamp that reabsorption is minimized. This mechanism results in gains in addition to those derived from use of optimum mercury vapor pressure.

The VHO lamp, rated at 100 watts, certainly must have discharge end losses in the neighborhood of 20 watts, as a consequence of cathode fall. This would leave approximately 80 watts for the positive column. The curve of light output vs positive column watts of Fig. 5 indicates neon to be somewhat inferior to argon at the 80-watt point. Can the authors explain how neon is advantageous at this value of loading?

With known types of cathodes, we suggest the adherence to A. W. Hull's teachings regarding cathode design for use in low pressure neon, *viz* thermionic emission of the full amount of current *required*, to avoid destructive sputtering. This is likely to require a substantial amount of cathode heating energy, which *must* be included in rating the lamp's efficiency.

Vapor pressure control by the use of a small cool area in the bulb has long been recognized in a number of types of gas discharge lamps, and is therefore, not new or surprising.

In the power groove lamp, we have already obtained the desirable parameters discussed in this paper, but by a dif-

*Jefferson Electric Co., Bellwood, Ill.

*Large Lamp Dept., General Electric Co., Nela Park, Cleveland, Ohio.

ferent means. The unique geometry of the power groove design accomplishes these objectives in the following ways.

(a) Electron temperature is increased by virtue of greater ion losses to the walls. This occurs because of greater ratio of wall area to discharge path volume.

(b) Resonance radiation is imprisoned less because of closer proximity of the walls to the discharge.

(c) Mercury pressure is controlled by many, nearby cool zones of the bulb — namely the edges of the grooved cross-section.

In addition, the power groove lamp accomplishes this with conventional argon filling gas, with resulting advantages in life, end discoloration and lumen maintenance.

1. W. Uyterhoeven and C. Verburg., Comptes Rendus Acad. Sci., Paris, 202, 1498 (1936).
2. W. Uyterhoeven, "Gasentladungslampen," Julius Springer, 1938, section 59.

R. N. THAYER:* The authors have well stated the case for the utility of high-brightness fluorescent lamps, and have described interestingly the characteristics of one lamp design to meet this objective. A quite different design solution, announced earlier, is that of a special bulb shape. This development has been called the "power-groove," and some parts of this discussion involve comparisons of these two lamp design approaches.

One of the two major features of the high-output lamp design described in this paper is the change in filling gas. Instead of argon, used in most fluorescent lamp designs to date, including power-groove, it uses neon. Neon is a much lighter gas than argon, and has a higher ionizing potential. These inherent properties commonly result in much faster cathode sputtering. Consequently, lamp life is short, end-discoloration severe, and lumen maintenance subnormal. Can the authors offer us any data on their design with respect to these performance items?

In some lamp designs — sodium vapor lamps, for example — the use of neon as a filling gas is required, for various reasons, despite these handicaps. Then, large cathodes and relatively high cathode heating wattages are used to minimize cathode sputtering, and the resulting short-life and end-discoloration troubles. Technical information released by the authors' company on the cathode wattage required for the 100-watt VHO lamp design indicates a steady cathode consumption of about nine watts, but this wattage is not included in rated lamp wattage by their recommended method of measurement. So, its inclusion would reduce rated efficiencies by about 9 per cent. The recommended measurement method for power-groove and other rapid-start lamps, on the other hand, does include in rated lamp wattage approximately the equivalent wattage consumed by cathode heating. Shouldn't this cathode wattage consumption be included in the VHO lamp wattage rating?

The second major feature pointed out for the design described in this paper is attainment of maximum light output and efficiency by the "discovery" that one cool spot in the lamp governs the vapor pressure in the whole lamp. It is hardly proper to call this a discovery. All fluorescent and sodium lamps, and many mercury lamps operate in accordance with this fundamental physical principle, which has been known for many years. The severe fall-off of 30 per cent in light output shown in Fig. 3 for mercury pressures built up by center bulb-wall temperature at this high wattage does require a cooler area for recovery, which is provided in large end-chambers at the expense of a considerable dark area at each end of the lamp. In the power-groove lamp, the "rails"; i.e., the edges of the grooved tube, run relatively cool because of their distance from the center of the arc. So, they act to control mercury vapor pressure in this lamp design and thus increase its light output. Fluorescent lamp designers have long known and published the independent effects of vapor pressure and current density (power input) in determining light output and efficiency, but it is only in high-output lamp designs that enough gain is possibly realized from specially constructed cooler areas to justify the added expense and complications of lamp design.

We want, finally, to confirm and emphasize the authors' caution that all high-wattage fluorescent lamps require close attention to full ventilation and good heat dissipation in fixtures if their full light output is to be realized. In addition, it should be realized that more attention to brightness control is required in many applications.

J. W. STRANGE:* It is a great pleasure to be with you today and particularly on this occasion when these two papers are being presented. To a certain extent I am reminded by this morning's session of a performance of Julius Caesar at the Old Vic Theatre which I attended some weeks before coming over. You will remember Mark Anthony's speech, "I come to bury Caesar, not to praise him," but I must admit on this occasion my attitude is different because far from wishing to bury this particular product, I am completely overwhelmed by the achievement of the authors in producing this new lamp. It is deceptively simple, so simple that I must admit my first reaction was to kick myself for not having thought of it first. It seems simple in some ways, but we may easily under-rate the lamp and the work that has gone into it. I think, however, we can easily counteract that impression by examining the various papers that have come from the authors and their associates over the last two or three years which undoubtedly laid the foundation for this development. It is certainly *not* a simple lamp.

Mr. Thayer has just compared the use of the cold spot in controlling the mercury pressure and the use of neon to previous experience with mercury lamps and sodium lamps. It surely is a complete misunderstanding of the operation of the lamps. Sodium lamps, for example, and we use a great number in England, are operated in a vacuum jacket which, as nearly as possible, insures complete uniformity of temperature throughout the lamp. The operation of high pressure mercury lamps is based, as far as I know, on controlled mercury pressure, achieved by careful design of the bulb to get uniform temperature, and by the careful control of the mercury content. I thought I would mention those two points after hearing what Mr. Thayer has just said. His misunderstanding emphasizes the fact that this paper has produced something quite unexpected, simple, deceptively simple, and I think it is a development of real value.

I think there is a second point in this development which is important to all of our experiments. As manufacturers, we have been playing around with all the parameters; the sizes, the lengths, the shapes, the fill gas, the fill gas pressure and so on. We tended to look the other way, looking for krypton to reduce the elastic collisions and there, staring us in the face, if we only had the physical knowledge to interpret it, was the fact that we could increase our loading by the use of these other gases. It is this combination of two features which, I think, makes this a unique lamp and a

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*Thorn Electrical Industries, Ltd., Engfield, England.

really great step forward in the rather picturesque phrase, "This is the lamp that has broken the heat barrier." Speaking now as a fixture manufacturer as well as a lamp manufacturer, we all know the problem that heat has presented to us, particularly when we are trying to punch out more light from a given length of fixture.

Now leaving that aside there are just a few further comments I have to make. As a former phosphor chemist, one subject greatly interests me; that is lumen maintenance. Undoubtedly with this high loading there will be a problem of lumen maintenance and I would like to ask the authors whether they have any information yet. I realize I am being a little unfair in asking for it so soon, but it would be interesting to hear whether these lamps behave in the same way as others and follow the Butler-Lowry equation which we heard about this morning. We have had quite a lot of experience with that equation and its application with higher loading lamps. As you know, we operate and have operated for many years an 80-watt T12 lamp which in its early days was a grossly overloaded and inefficient lamp. We were rather ashamed of it. But as lamp phosphors improved and as lamp processing improved, instead of being an overloaded lamp it is now a very efficient lamp and is in a very strong position in relation to lower loaded lamps, like the four-foot 40-watt. So we are impressed by the possibility of giving the phosphor today a good hard job to do and I am wondering whether they have any information on that particular point. We do know for example that the exponents of the Butler-Lowry equation are pretty well proportional to load. Now that may mean that this new lamp has worse maintenance than the current lamps, but I would say that in my view, even with its poorer maintenance, it may well have a very important part to play in the lighting industry.

We come across the problem of getting more light out for a given length. For example, we have done a lot of work on use of fluorescent lamps in floodlighting, theatre use and so on. Time and again there is the problem of getting more light out per foot of run. When you pack in all the 40-watt lamps you can get and you find them interfering, you have reached a maximum. Now if by redesign of lamps you can punch in more light, it will open up fields that we have not touched. That applied equally well to street lighting where it is the design of lamp combined with the design of fixture which determines what you can achieve.

I have found this a most enthralling lamp and I can only finish by paying a real tribute to these authors not only to the way they have done the work but also in the way they have presented the papers at this meeting.

JAMES COX:* This is an interesting approach to obtaining more light from a given bulb size without changing its configuration.

The use of a shield or trap to control the vapor pressure and the use of neon gas is a new departure from the conventional way of making fluorescent lamps; although the principle of controlling mercury vapor pressure in a lamp by use of a cooling chamber is described by Mr. Macksoud as early as 1942 in U. S. Patent Number 2,277,876.

It would be interesting to know what this lamp could do at higher loading; it is conceivable that greater gains could be achieved. The operating principle of mercury vapor pressure control opens up a whole new field of investigation for more heavily-loaded, higher light output lamps.

The shadow caused by the shield is rather objectionable and I imagine that the authors are working on various ideas to eliminate or minimize this effect. Perhaps a different type of shield construction or the use of amalgams might help.

Elenbaas, in "Fluorescent Lighting" (edited by C. Zwikker), page 85, has shown that for a given current, mercury vapor pressure, tube diameter and rare-gas pressure, the fluorescent lamp life is shorter for neon filled lamps than for argon lamps. This causes one to wonder whether or not the same applies to VHO lamps and to raise the general question of life for this lamp type.

Lumen maintenance data are conspicuous by their absence from Mr. Gungle's paper and the end discoloration may be greater in this lamp due to more parts to degassify. I wonder if the authors will care to elaborate on these two points.

Inasmuch as the bulb wall is operating 40-50C hotter in the VHO lamps than in regular fluorescent lamps the question is raised as to what effect this has on phosphor output. In other words, what is the temperature dependence of luminescence characteristic of the phosphor used in VHO lamps? Was a new phosphor developed for this lamp?

Was the choice of color purely arbitrary? Will other colors be available? Do efficiency figures include losses in filaments? Is the ballast loss proportionately higher than in regular fluorescent lamps?

From a commercial standpoint, I would like to point out the advantages of this new light source.

(1) Increase in light per foot of bulb without appreciable loss in efficiency.

(2) The use of bulbs of conventional diameter and cross section.

(3) More light economically by:

A. Using fewer lamps to obtain a given lighting level.

B. Using less fixtures.

C. Fewer lamps to buy and stock.

These factors tend to lower the initial cost.

The disadvantages might be:

(1) Use of larger, heavier, more costly ballast.

(2) Design of a completely new line of fixtures for better shielding and heat dissipation.

JOHN F. WAYMOUTH:* To begin with, I would like to express my personal appreciation for the compliments that various discussors have offered with their discussions of these papers. I am sure I speak for Dr. Bitter, Mr. Gungle and Mr. Homer as well as all the members of our laboratories in saying "Thank you very much."

With such a mountain of questions before me, I think it will probably be best to discuss them more or less in increasing order of complexity.

First of all, let us take up questions having to do with the actual performance of the lamp.

(1) *Life.* In this day of rapid-start operation of fluorescent lamps, designing cathodes for maximum life is not nearly so great a problem as it used to be. In particular, there is less and less dependence on the filling gas to protect the electrode from ion bombardment, and more dependence on adequate cathode heating. This lamp will have normal life. Discoloration will be no worse than in other heavily-loaded lamps, such as the 100-watt 72-inch street lighting lamp. It will probably be less noticeable because it will occur in a region of the bulb which is not brightly lighted—that is, near the cool ends.

(2) *Lumen maintenance.* Our tests show that 3000-hour

*Tungsten Products Corp., North Bergen, N. J.

*Co-author.

lumen output is at least 75 per cent of the rated initial value. This figure is only slightly less than that for some other commercial lamps. Moreover, we have every expectation that it will be improved.

(3) *Phosphor color and temperature dependence.* The temperature dependence of the phosphors being used is such that the fluorescent efficiency of the phosphor is down only a few per cent at the temperature of operation of the bulb. The lamp will probably eventually be supplied in several of the more popular colors.

(4) *Ballast losses and cost.* This is a problem which is more properly that of the ballast and fixture manufacturers. Mr. Robertson has pointed out that the cross-section of the ballast will have a great deal to do with its losses, and the selection of this cross-section, of course, is influenced by the desires of the fixture manufacturers. Aside from these considerations, there is no reason why ballast losses should be proportionately any different from any other rapid-start lamps. In fact, the favorable ratio of lamp drop to open circuit voltage, and the relatively low current to obtain the rated wattage, of the VHO lamps should tend to reduce ballast cost and losses.

(5) *Concentration of mercury at the walls.* Our calculations indicate that at the currents encountered in VHO lamps the vapor density of mercury atoms is not appreciably greater at the walls than at the axis, despite the "ionic pumping" due to ion current to the walls.

(6) *Neon versus argon at 100 watts.* Mr. Aicher has correctly pointed out that the discharge end losses must be taken into consideration in connection with Fig. 5 of the paper by Waymouth, Bitter and Lowry. However, this correction is considerably larger in argon than neon because of the higher current necessary to reach 100 watts in the argon-filled lamp. In actual lamps including end losses, there is still an advantage to the use of neon at this power level. Moreover, in connection with Table II of the Gungle paper it was pointed out that the lower current and high voltage obtained with neon simplifies the design of the electrode and the ballast.

Second, let us consider questions relating to the applications of the VHO lamps.

(7) *"Dim ends."* We do not believe that "dim ends" will be a serious objection in any of the applications in which the VHO lamps will find their greatest use. They are: street lighting and outdoor floodlighting; high bay factory lighting; and such special indoor applications as behind luminous ceilings, egg-crate ceilings and the like.

(8) *Effect of fully enclosed fixtures.* It is well known that with any fluorescent lamp, the ambient temperature of importance is the temperature of the air surrounding the lamps. In fully-enclosed fixtures, the temperature of the air inside the fixture is substantially greater than the temperature of the air outside the fixture. Despite its higher wattage, the VHO lamp is at no disadvantage compared to other lamps so far as operation in fixtures is concerned; see, for example, Table V of the paper by Gungle, Waymouth and Homer. Moreover, the VHO lamp has the very decided advantage that it is easy for the fixture manufacturer to provide means for keeping the cool-spot at its rated temperature of 40° even when the air temperature in the fixture is higher than 25°C. We have found that in fully-enclosed fixtures of the street-lighting type that the *ends* of the fixture itself are frequently at a temperature of 40C or lower when the ambient temperature *outside* the fixture is 25C or higher. A simple metal contact to the cool end of the lamp, conducting heat to the end of the fixture (a "heat sink") can keep the condensed mercury temperature down. As pointed out in the paper by Gungle, Waymouth and Homer, a particular advantage of this is the ease with which thermostatic control can be built into these heat conducting contacts, so that proper condensed-mercury temperatures can be provided over a wide range of outside ambient temperatures.

(9) *Vertical or inclined operation.* The mercury-vapor pressure in the lamp will ultimately be determined by the temperature of the coolest spot in the lamp. Therefore, even though the upper end of the lamp in vertical or inclined operation is too hot, the vapor pressure of mercury will be held down by the lower cool end, which if anything will run a little cooler than normal.

Several of the discussers have taken exception to the method of measurement of power input to the lamp for the determination of efficiency. This was not a topic discussed in either paper; therefore, it is necessary to take a few moments to elucidate the differences from past practice and to give our reasons for them.

In the past, it has been customary to measure light output and wattage input to rapid-start lamps by disconnecting the filament circuits and operating the lamp with bombardment heated cathodes, measuring light output and wattage. With the filament circuits reconnected, the lamp potential drop goes down somewhat; it has been *assumed* that the lamp wattage goes down by an amount equal to the filament heating wattage consumed, and that therefore the lpw measured by the two-wire circuit is the same as the lpw in the four-wire circuit including filament watts. This is not necessarily a valid assumption. The lamp wattage can go down only by an amount equal to rms lamp current times the reduction in rms cathode fall. It is well known that cathode fall does not decrease indefinitely for a given cathode as the filament heating wattage is increased; therefore the reduction in lamp wattage cannot possibly compensate for the filament wattage added, above a certain critical value. Since this critical value depends on the design of the coil as well as other factors, it does not follow that the past practice in measuring rapid-start lamps has automatically included the filament heating wattage in the lamp rating.

The method recommended for measurement of the VHO lamps is that the wattage input to the lamp is measured with the filaments separately heated. The potential coil of the wattmeter is connected across the highest potential difference across the lamp. The lamp is therefore measured as it would normally operate. In measuring lamps at the high currents encountered in the VHO/25 lamps, and especially at the still higher currents anticipated in the future, we believe it to be essential to measure in this way to prevent damage to the cathodes during the act of measurement itself.

Since past practice is not fundamentally correct, and since we feel that it is bad for the lamp, we have adopted the method described above. What the customer ultimately is concerned with, anyway, is not the lamp lpw but lamp lumens (or better yet, footcandles on the working surface) divided by ballast input watts.

Mr. Thayer and Mr. Aicher have made the comment that no discovery is involved in the use of a cool spot to control mercury vapor pressure in gas-filled fluorescent lamps. In this connection, it is perhaps interesting to quote from a paper in this journal as recently as 1954 by L. J. Buttolph.[1] Speaking particularly of the fact that efficiency goes down as mercury pressure goes up in fluorescent lamps, and reasoning from the known fact at that time that mercury pressure inexorably increased as power input was increased,

Buttolph said, "Efficiency and very high output intensity are incompatible in such lamps."

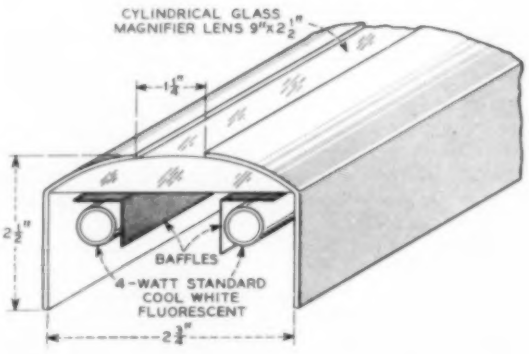
In discussing this point, both Mr. Thayer and Mr. Aicher have described the effects observed in "power groove" lamps, which are designed to operate at approximately the same loading as the VHO lamps. They have pointed out that in the power-groove lmps, the mercury condenses in the "rails" which are the coolest part of the bulb. This approach to the solution of the problem still suffers from the same limitation as that described by Buttolph. Raise the power — the mercury pressure goes up. By virtue of its different shape, the power-groove bulb is just on a different curve of mercury pressure versus power input.

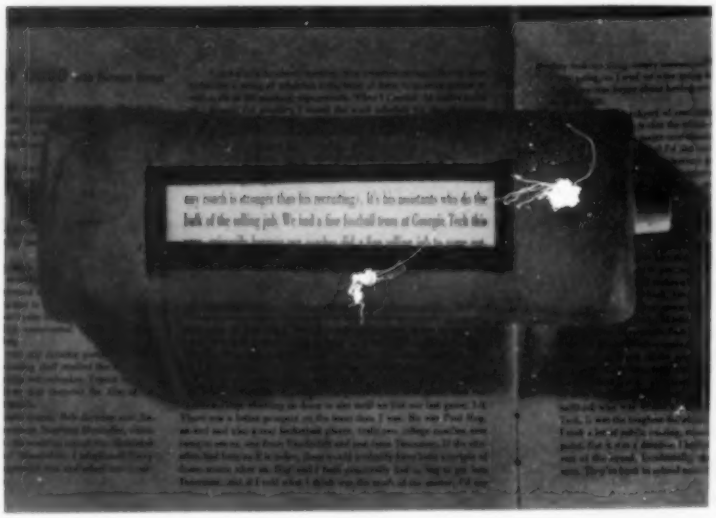
By contrast, the method used in the VHO lamp permits mercury pressure and power input to be independent variables. The limitation recognized by Buttolph has been shattered. By suitable changes in mount design, the condensed mercury temperature, and hence mercury pressure, can be made optimum at any desired value of power input, in the same bulb diameter. Only a further major change in geometry would permit the power-groove lamp to operate at optimum vapor pressure at 50 watts per foot, for example.

1. Buttolph, L. J.: "Characteristics of Mercury in Lamps," ILLUMINATING ENGINEERING, Vol. XLIX, No. 7, page 321 (July 1954).

Illuminated Magnifier for the Near-Blind

For many aged and other visually-handicapped people, reading can be difficult, if not impossible, however good the normal lighting might be. The device shown was developed originally to accommodate just such a person, a friend whose aged eyes had almost totally failed. Increased general illumination was tried first, but for these eyes had a visual "fogging" effect. Subsequent attempts to aid the old gentleman's feeble vision led to the development of the device shown in the drawing. Two 4-watt fluorescent lamps, placed as shown, provide about 350 footcandles on one or two lines of type, which are at the same time magnified. The device has enabled this near-blind person to read the relatively small print of his favorite magazines. Developed as a solution to a lighting problem by Floyd Sell, Detroit Edison Co., Detroit, Mich.

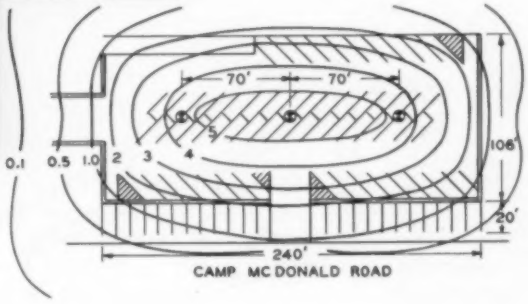




Illuminated magnifier in operation.

INSTALLATION AT PROSPECT HEIGHTS, ILL.

(Below) Isolux chart showing horizontal footcandles.



Lighting a Shopping Center Parking Lot

LIGHTING OBJECTIVE: To provide an attractive parking lot with appeal to passing motorists and to enable those using the area to locate their automobiles easily and safely.

GENERAL INFORMATION: This shopping center is located beside a main highway. The 240-foot by 106-foot parking area is paved with black top. A street parking area is adjacent on one side.

INSTALLATION: An average illumination level of 4 footcandles is provided by three Revere Electric Manufacturing Co. Ultralite units #5440 mounted 34 feet high and spaced on 70-foot centers. Each luminaire is equipped with four 400-watt E-H1 mercury lamps. The controlled beam from the street lighting refractor produces a good shielding angle with high utilization and a square pattern of light.

Architect: Jens J. Jensen, 110 South Dearborn St., Chicago, Ill.

Engineers and Contractors: Berry Electric Contracting Co., 2045 West Lake St., Chicago, Ill.

Lighting data submitted by Wallace W. Weld, Revere Electric Manufacturing Co., Chicago, as an illustration of good lighting practice and to aid in the design of similar installations.

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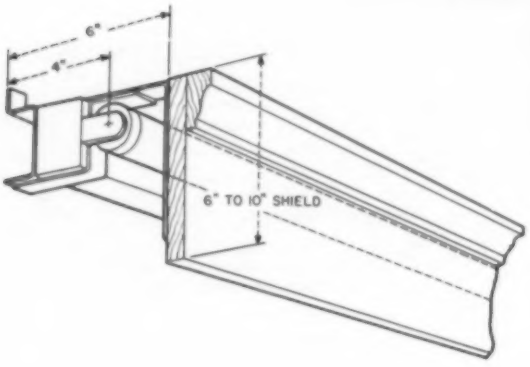
Series XXII 5-57

A.I.A. File No. 31

General illumination from the valance provides indirect lighting from ceiling and drapes. Accent lighting is from the lighted china cabinet at the right, built-in and concealed from casual view. Sparkle is added by a recessed pin-hole downlight over the table.

Detail of a valance, giving both up and down light. The lamp should be located at least four inches from the surface to be lighted. This same dimension is commonly used for lighting curtains and flat wall surfaces.

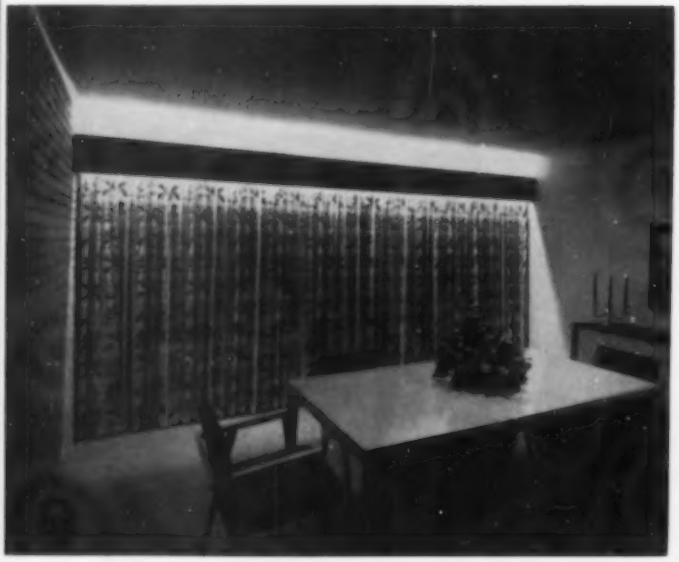


Designed

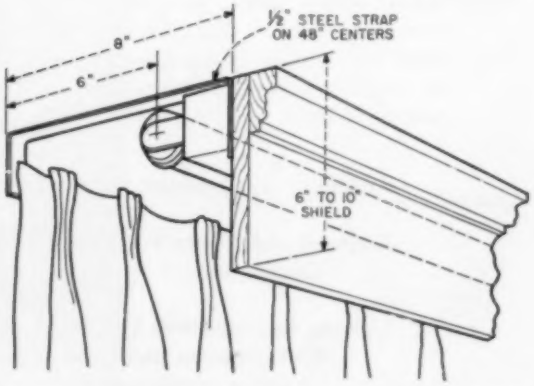
I—General Illumination

LIGHTING can be designed to make our homes more livable and beautiful. To achieve this, we must study the function of a house to plan sufficient levels of illumination in the right places. We must study the style of a house to make the lighting blend with it and seem a part of it. We must study the furnishings to enhance them.

There are two basic forms of light which can be combined in varying degrees to produce comfortable and satisfying interiors: general light and accent light. General light should be diffused and



With heavy lined drapes, a special construction is necessary to allow the light to flow down the front of the drapes, which hang three to four inches from the wall.



Strip is mounted on valance board and supported with ½-inch steel straps on approximately 48-inch centers. In photo at left, pin-hole spot provides accent over table.

A popular means of having general reflected lighting today is by lighting walls. In addition to wall lighting, this room has a cove to light the ceiling (not turned on in this photo) and recessed downlights over the furniture groupings to give accent. Each of these three systems is switched separately and dimmer controlled in a projection room to the left.

Lighting in Homes

By RUTH PATTERSON

partially reflected by floors, walls and ceilings. It should soften harsh shadows. Accent light focuses attention. It is the light on a picture or a planter, or the puddle of light around a chair. Because we use our homes for such a wide variety of purposes, we must combine and control these two kinds of light individually to meet varying needs.

In the examples shown here, of new and remodeled residences, general illumination is predominant. In a future issue of I. E. installations showing accent lighting will be featured.

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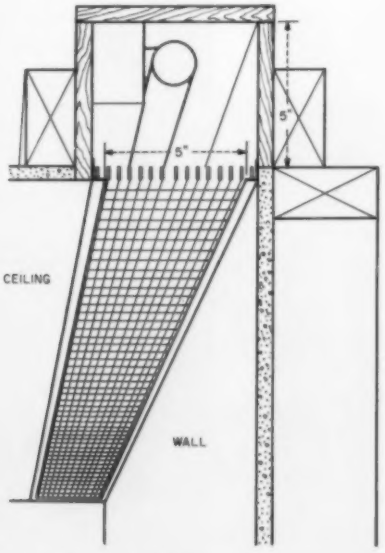
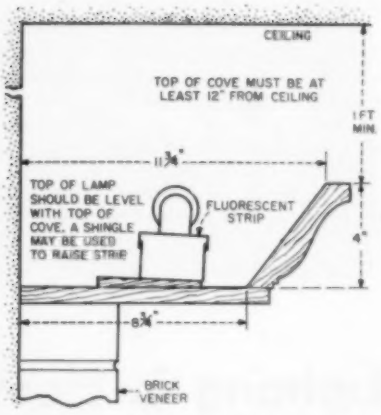


Sometimes owners, decorators, or architects do not want an 8-inch board extending below the ceiling. In this case the light may be recessed. A 5-inch wide trough is built to conceal a single row of fluorescent lamps. The box, 5 inches wide by 5 inches deep, has a glass or cast plastic louver as a diffuser at the ceiling line.

Another type of indirect lighting is from the ceiling or cove lighting. Cove lighting creates a more formal atmosphere, and is also sometimes more difficult to use in modern homes where ceilings are low and tops of windows high. Brick veneer has been added to the walls and a cove installed 15 inches from the ceiling in this remodeled living room.


CEILING
TOP OF COVE MUST BE AT LEAST 12" FROM CEILING
1 FT MIN.
11¾"
TOP OF LAMP SHOULD BE LEVEL WITH TOP OF COVE. A SHINGLE MAY BE USED TO RAISE STRIP
FLUORESCENT STRIP
4"
8¾"
BRICK VENEER

Cove was built of walnut molding to match the paneling. Two points which must be observed are: lip of cove must be at least 12 inches from the ceiling, or light will create a hot spot just above the cove but will not carry out across the ceiling; also the top of the lamp must be level with the top of the cove. Light source should not be visible.

Cove lighting, in a contemporary structure, is installed with a slanting ceiling, resulting in greater uniformity.

Accent lights are used close to the far wall to emphasize the rough texture.

All four walls of this bedroom have coves on dimmer control, for various illumination levels. Three good portable lamps, two at the bed and one at the chair at left, provide accent in the room.

This dressing room has mirrors almost solid on three walls. A combination of direct and indirect lighting is used: standard fixtures furred in at the top of the doors, leaving enough space above for a cove to light the center of the ceiling.

In a model home* recently built in Texas, clerestory window on one side of the living room balances a complete wall of sliding glass panels on the opposite wall. A cove, located just below the clerestory, provides uniform indirect lighting over the room. Portable lamps supply accent. Cove is about four feet from the ceiling.

*A Pacesetter House, sponsored by the Dallas Power & Light Co., and the General Electric Lamp Division for *House Beautiful*. Architect: Harwell H. Harris, at that time Dean of the School of Architecture, University of Texas.

In the dining room of the model home, two hollow beams, running the length of the room, each conceal four 100-watt lamps. Ceiling has high reflectance finish. Luminous ceiling above pass-through to the kitchen is lighted from above by two 100-watt lamps in 24-inch deep cavity.

Kitchen has a window wall above the work counters at the left, and a clerestory provides balanced daylight on the other side. Indirect lighting is from the closed portion of the hollow beams (48 inches on centers) and downlight through plastic louvers on the underside of the beams. Far wall is lighted by a continuous valance and work lights are concealed over the surface cooking units. A continuous lighted soffit provides 40 footcandles on work counter and sink at left.

Entrance walkway is lighted by hollow beams containing 40-watt lamps on 48-inch centers. Floodlamps mounted in the garage, at left, are aimed through a louvered wall to light the green ground cover.

Phosphors for High Pressure Mercury Lamps

By M. J. B. THOMAS
K. H. BUTLER
J. M. HARRIS

DURING the past decade the high pressure mercury vapor lamp has become a light source of rapidly increasing importance both for outdoor lighting and for indoor industrial lighting. Historically, some attempts were made early in this century to use mercury vapor lamps for lighting. However, the first practical high pressure lamp was developed in Germany in 1931 when it was established that heated cathodes combined with use of an accurately measured amount of mercury gave stable electrical characteristics. The possibilities of this light source were seen at once and since the initial incubation period there has been a steady acceleration in lamp production and in the variety of types available. While the present day blue-white mercury light is no stranger to the lighting engineer, complete acceptance by the public has been less rapid because of color distortion.

The visible radiation from the HPMV lamp consists almost entirely of the line spectrum of mercury with intense lines at 405, 436, 541 and 578 millimicrons. The color rendition[1] is fairly satisfactory for deep blue, green and yellow objects, somewhat less satisfactory for blue green and extremely poor for red or purple objects, which become brown or blue in hue.

This deficiency in red was recognized almost immediately and attempts were made to correct it in various ways. One effort was the use of cadmium amalgam instead of pure mercury. The cadmium spectrum from the arc contributed some added lines in the blue, green and red which gave some color correction but did so at a considerable sacrifice in efficiency. Another effort was the use of a sulfide phosphor coating on the outer jacket of the lamp. A lamp combining these methods was marketed in England for some years. A third effort to correct the red deficiency was the use of a tungsten filament source as an integral part of the mercury lamp.

From these early efforts in correcting the red deficiency it became increasingly obvious that special phosphors had to be developed, since most fluorescent powders could not be used effectively in these lamps. A better understanding of the problem of color correction requires some knowledge of the construction of the HPMV lamp, and of the whole spectrum of radiated energy before the requirements for a suitable phosphor can be visualized.

With few exceptions, the HPMV lamps made in this country use a quartz arc tube transmitting ultraviolet radiation down to approximately 200mμ This quartz arc tube is supported inside an outer jacket filled with nitrogen. When the lamp is operating the nitrogen pressure is approximately atmospheric. This outer jacket becomes quite hot when the lamp is operating, reaching a temperature from 150° to 350° C depending on fixture design and lamp wattage.

Spectral Energy Distribution in the HPMV Lamp

In addition to the visible line spectrum, HPMV lamps made with a quartz arc tube emit a large amount of ultraviolet energy, which can be converted to visible light, by the use of phosphors. Data in Table I and Fig. 1, summarized from Elenbaas,[2] show that a 250-watt HPMV lamp has a total of 33.6 watts of ultraviolet energy, divided into 8.00 watts of energy below 260mμ, 15.40 watts of energy between 260 and 320mμ and 10.20 watts of energy between 320 and 400mμ. By comparison the visible lines contain only 21.44 watts of radiant energy as shown in Table II. When considering the utilization of the ultraviolet energy by phos-

TABLE I.

Wavelength Range	Energy in Band		Equivalent 600mμ Energy		Equivalent Lumens
below 260	8.00	8.00	3.48	3.48	1493
260-280	3.73		1.65		
280-300	3.27	15.40	1.57	7.55	3239
300-320	8.40		4.33		
320-340	1.00		0.86		
340-360	1.15	10.20	0.35	6.15	2638
360-380	7.80		4.77		
380-400	0.25		0.17		
Total u.v.	33.60		17.18		7370

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 17-21, 1956, Boston, Mass. AUTHORS: Sylvania Electric Products Inc., Salem, Mass.

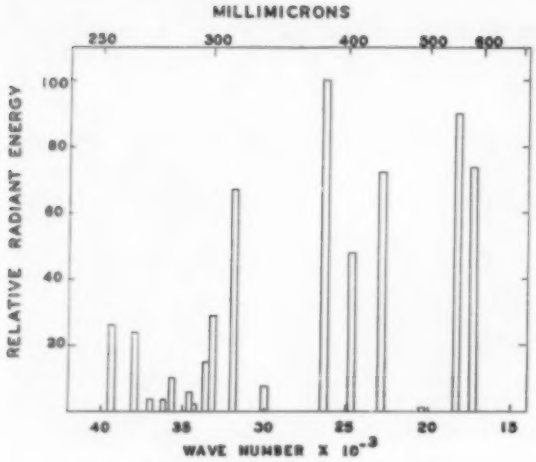


Figure 1. Line spectrum of HPMV lamp.

phors the theoretical equivalent energy at any chosen emission wavelength can be calculated by multiplying the actual ultraviolet energy by the quantum ratio, which is the ratio of the exciting wavelength to the emission wavelength. Thus, data for the equivalent watts of 600mμ orange red emission are given in the third column of Table I and show that 17.18 watts of visible light would be added by the complete conversion of the ultraviolet energy in this 250-watt lamp. For other sizes the gain varies somewhat as the u-v output depends on pressure in the arc.

While the actual radiant energy of a light source is of great importance in determining its efficiency, it is but one of the factors to be considered. From the standpoint of color rendition the distribution of this energy through the visible spectrum is also vital and the concentration of the radiant energy of the HPMV lamp in three lines (blue, green and yellow) gives severe color distortion.

The color of objects is determined by the relative intensity of various wavelengths in the reflected light. Blue objects reflect blue and absorb green and yellow so that the amount of blue light in the spectrum of the source determines their appearance. Similar conditions hold for all colors, so for good color rendition, the source should have light of wavelengths which will be reflected by the object. The almost complete lack of red in the clear mercury lamp results in severe distortion of appearance for orange, red and purple objects.

In addition to radiant energy distribution in the source the varying sensitivity of the eye to different wavelengths must be considered. From the luminosity curve[3] it is apparent that the lumen efficiency of a source is greatest when the emission is concentrated in the middle of the visible spectrum. Therefore, the radiant energy must be corrected for the varying eye sensitivity by the use of lumen output as a measure of the light emitted.

The third column of Table II shows the relative lumens produced by the visible line spectrum. The fourth column of Table I shows the lumens theoretically possible if all the ultraviolet energy could be converted into orange red light.

There are two points of great interest in these data. First, the blue lines of the mercury spectrum contribute very few lumens even though they have 43 per cent of the total visible energy in watts. Second, if all the ultraviolet energy could be converted into orange red light the total lumen output of the lamp would be nearly doubled. However, this theoretical figure can never be quite realized because the quantum efficiency of phosphors is always below 100 per cent and also because the phosphor coating will absorb some of the visible light from the arc tube. Even allowing for these losses, it would be still possible to gain 50 per cent to 65 per cent in lumen output if suitable phosphors were available.

TABLE II.

Wavelength	Energy in Line	Equivalent Lumens
405 and 407	3.59	2
436	5.45	65
492	0.07	11
546	6.78	4541
578	5.55	3355
Total visible	21.44	7974

Phosphor Requirements

In the past twenty years tremendous gains have been made in fluorescent lamp performance by phosphor improvement. These phosphors were developed to meet specifically the demands placed upon them by the low pressure discharge. These requirements can be stated simply.

1. They must respond efficiently to 254 mμ radiation.
2. They must be stable to the effects of 185 and 254 mμ radiation and to the effects of mercury ion bombardment.
3. They should have broad emission bands since good color rendition is required in most applications of fluorescent lamps.

By their very nature these efficient phosphors cannot be effectively used in HPMV lamps where the requirements for phosphors are quite different. For full utilization of the potential value of phosphors in the HPMV lamp the following unique requirements must be met.

1. They must respond efficiently to a wide range of ultraviolet wavelengths, with response to 313 and 365mμ being especially important.
2. They must retain high fluorescent efficiency at elevated temperatures.
3. They must be stable at high temperatures to the effects of ultraviolet and to chemically active gases in the lamp envelope.
4. They should have a substantial part of their emission in the long wavelength end of the spectrum if color rendition of reds is to be improved.
5. They should emit near the middle of the visible spectrum, in addition to the red, if loss of lumen output is to be avoided.

Sulfide Phosphors

The first phosphors tried in HPMV lamps were zinc-cadmium sulfides, activated by silver or copper which can be made with a wide range of emission colors.[4] To obtain a reasonable amount of red emission it is necessary to have a considerable amount of cadmium sulfide in the composition. This introduces a strong absorption band in the blue and as a result the phosphor coated lamp becomes deficient in blue. Other difficulties with the use of sulfide phosphors arise from their poor stability when exposed to ultraviolet below 340mμ and also from their rapid loss of fluorescent efficiency at high temperature.[5] This last defect makes it necessary to use an oversized outer jacket on the lamp to reduce its temperature to the efficient operating temperature of the phosphor.

Manganese Activated Phosphors

The obvious deficiencies of the sulfides soon inspired a search for other possible materials and there has been a gradual development over the last ten years of several useful phosphors containing tetravalent manganese as the activator. These include the titanate, the arsenate, the germanate and the antimenate of magnesium. All of these phosphors show emission in several very narrow bands in the deep red (640 to 680mμ). Since the visual effectiveness of the deep red emission from these phosphors is very low, the lumens contributed by the phosphor coating are not sufficient to overcome the loss on lumens caused by absorption of the mercury lines by the coating. Hence lamps made with these deep red emitting materials have a lower lumen output than lamps with a clear glass bulb. The color rendition for reds is greatly improved but, in general, the rendition of blues and blue-greens is less perfect since all of these phosphors absorb the blue line of the mercury spectrum to some extent. A very brief description of the four phosphors is included here to allow comparison with more recent developments.

The fluorescence of magnesium orthotitanate has been described by Kroeger.[6] It can be excited by wavelengths between 280 and 520mμ with a peak efficiency of 55 per cent at 325mμ. The amount of blue light is decreased appreciably due to its broad absorption band and there is also some absorption of the green and yellow emission lines of mercury. The preparation is rather difficult with a very long firing cycle being required. No practical use has been made of this phosphor.

Magnesium germanate, activated by tetravalent manganese, which was originally reported by Leverens,[7] is a much more efficient phosphor than the titanate and was the first material used in color corrected HPMV lamps in this country. The properties of a modification of this phosphor, in which a higher proportion of MgO is used in the preparation, have been described by Kroeger.[8] A further modification in which MgF_2 is used to replace part of the MgO is described by Thorington.[9] While many of the properties of this phosphor are excellent it uses a very rare metal, germanium, in its composition so that its cost is very high and the future availability is questionable. The lowering of lumen output, mentioned above, has also been a hinderance to its usefulness.

Another important phosphor activated by tetravalent manganese is magnesium arsenate, reported by Travnicek. The properties of this phosphor have been described in several papers.[10,11,12] Like the germanate, this phosphor also decreases lumen output in color corrected lamps, gives excellent red rendition with some sacrifice in rendition for blues and blue greens. The availability and cost are satisfactory, but the composition is highly toxic due to the large amount of arsenic present. A more serious defect is the lack of chemical stability at high temperature which limits the use to 100- and 175-watt lamps where the bulb temperature is about 200°C, as compared to 300°C for the higher wattage lamps. Even in these low wattage lamps a special fill gas containing CO_2 is needed and this may cause oxidation of the mount structure in time.

A fourth phosphor activated by tetravalent manganese is magnesium lithium antimonate, described by Ranby.[13] It resembles the arsenate and germanate both in excitation and emission properties and in composition, since there is a high ratio of magnesium and lithium to antimony. The availability and cost of raw materials are satisfactory and the phosphor has low toxicity. Its response to the whole ultraviolet spectrum is quite good, though less efficient than the germanate. The temperature dependence is also poorer which limits its usefulness.

Since there are only minor differences in the emission spectra the single emission curve shown in Fig. 2 represents the performance of the various phosphors activated by tetravalent manganese reasonably well. It is concentrated in the deep red as an extremely narrow band. The excitation spectra of the various phosphors are also shown in Fig. 2.

In addition to the phosphors activated by tetravalent manganese, a complex silicate activated by a combination of cerium and divalent manganese was recently described by Gooding and McKeag.[14] The emission of this phosphor consists of a broad band in the deep blue and a narrower band in the red while it is efficiently excited by a rather wide range of ultraviolet wavelengths as shown in Fig. 3. Unlike the germanate and arsenate this silicate phosphor improves both blue and red color rendition. The cost and availability are satisfactory but the use of trivalent cerium as an activator makes the phosphor difficult to handle in the manufacture of the lamp. Possibly this has prevented the introduction of this phosphor for color correction.

The efficiency of all of these manganese activated phosphors, and their emission and excitation spectra are all dependent on the exact composition of the matrix material and on activator concentration. The figures in this paper show representative spectra. In regard to temperature dependence the arsenate and germanate gradually improve in efficiency up to a temperature of 300 to 400° C, whereas the antimonate and triple silicate have maximum efficiency at about 130° C limiting their usefulness. Here again exact composition influences performance.

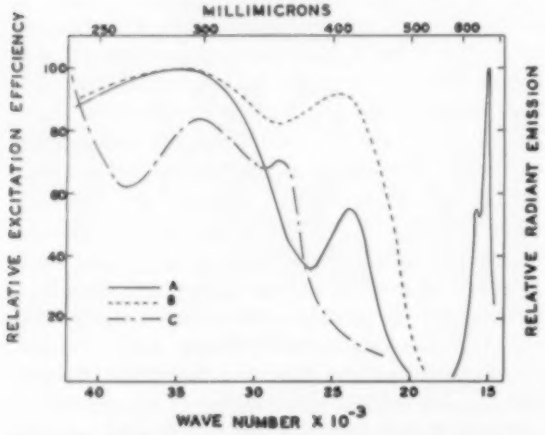


Figure 2. Excitation and emission spectra of phosphors activated by tetravalent manganese.

A. Magnesium Germanate
B. Magnesium Arsenate
C. Magnesium Antimonate

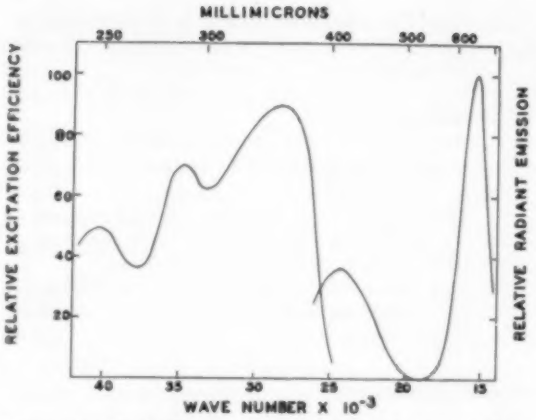


Figure 3. Excitation and emission spectra of cerium and manganese activated triple silicate.

Phosphate Phosphors

A group of tin activated orthophosphate phosphors which respond efficiently to 254mμ radiation, were discovered[15] some years ago. They have broad emission spectra and a considerable output of red and deep red light. Such phosphors are now used in a super-deluxe cool white fluorescent lamp, giving considerably improved color rendition in comparison with standard lamps or even with the deluxe lamps using a calcium silicate phosphor. In the previous investigation of these phosphors it was found that the emission spectrum of these phosphors depended considerably on the exact composition of the matrix. Continued study has shown that the excitation spectrum is also dependent on phosphor composition. Thus, by choice of the proper components for the matrix, phosphors with excellent response to all wavelengths below 320mμ can be produced.

The best of these new phosphors is basically a tristrontium orthophosphate, activated by stannous tin, in which zinc replaces a part of the strontium. This introduction of zinc causes a radical change in the emission spectrum since strontium orthophosphate, free from zinc, emits in the long ultraviolet while the phosphor containing a small amount of zinc has orange-red emission. The emission color is dependent on the exciting wavelength. With excitation by the longer ultraviolet, such as 313mμ the emission is solely in the orange-red. If shorter ultraviolet, such as 254mμ, is used an emission band is also found in the deep blue. Since in the actual HPMV lamp the exciting radiation contains all wavelengths between 200 and 320mμ, there is a small blue component in the phosphor emission curve. Fig. 4 shows the excitation and the emission curves of these phosphors.

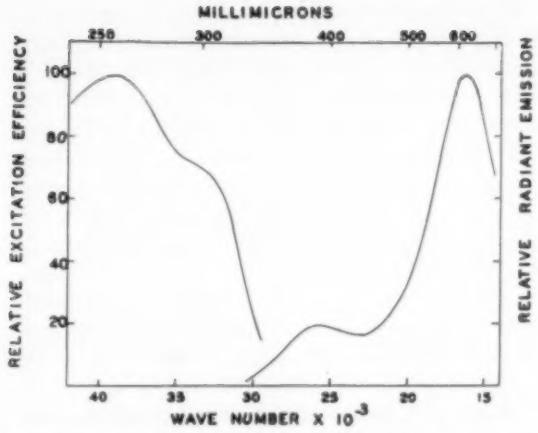


Figure 4. Excitation and emission spectra of tin activated Strontium Zinc Phosphate.

This new orthophosphate phosphor has definite advantages over the manganese activated compounds described in a previous section. It is potentially low in cost being made from readily available raw materials; it is non-toxic; it does not absorb the blue mercury lines; it utilizes efficiently a considerable part of the available ultraviolet of the mercury arc spectrum; and it is chemically stable.

This strontium-zinc phosphate has very satisfactory temperature dependence since its peak efficiency lies in the range of operating temperature of the more usual types of HPMV lamps as seen in Fig. 5. In addition, the red output is high so that in HPMV lamps this phosphor gives quite acceptable color rendition combined with an improvement in lumen output.

Lamp Performance

The development of the new ortho-phosphate phosphor has made possible a new line of color improved HPMV lamps including the 100-watt SH4, the 175-watt SH22, the 400-watt SH1, the 400-watt reflector type KSH1 and the 1000-watt SH15. This line of lamps gives color rendition of reds little below that of the older color improved lamps, while also giving a slight gain in rendition of blue and blue-green colors. In addition, instead of a sacrifice in efficiency, the SH line of lamps has efficiencies 10 per cent to 20 per cent above that of corresponding clear lamps.

Referring back to Table I it can be seen that utilization of all ultraviolet up to 320mμ will theoretically increase lamp efficiency 60 per cent. However, the various losses due to presence of coating and so on, cause about 15 per cent decrease in the overall efficiency of any phosphor coated lamps, reducing the expected increase to 35 per cent if the phosphor quantum efficiency is 100 per cent for this whole range of ultraviolet. It can be seen from Table III that the phosphate can give a considerable part of this expected increase in lumen output.

The curve of temperature dependence shown in Fig. 5 shows that the optimum bulb temperature for the strontium-zinc phosphate is about 180°C. This is close to the average bulb temperature of the 100-watt lamp in the PS25 bulb but is slightly below that reached in the higher wattage lamps. This decline in phosphor efficiency at high bulb temperatures hampers realization of the full benefit of the potential lumen gain from the phosphor coating in the higher wattage lamps in their present bulb sizes. This is not true in the low wattage SH4 and SH22 lamps.

Characteristics of the Emitted Light

Whereas in fluorescent lamps only eight per cent of the lumen output is due to the mercury lines and the efficiency and color rendition are determined almost solely by the phosphor, in the phosphor coated HPMV lamps 70 to 80 per cent of the total lumen output is due to the intense green and yellow lines of mercury with the balance of the light coming from the phosphor. Because of this major difference the same color rendition as fluorescent lamps cannot be attained even with the best color corrected HPMV lamps. The arsenate and germanate phosphors do give good red rendition but this is achieved only by a sacrifice of lumen output. In the manufacture of JH lamps, a deliberate compromise must be made between red rendition and lumen output. With the orthophosphate phosphors in the SH lamps the situation in somewhat different since the phosphor adds both to the lumen

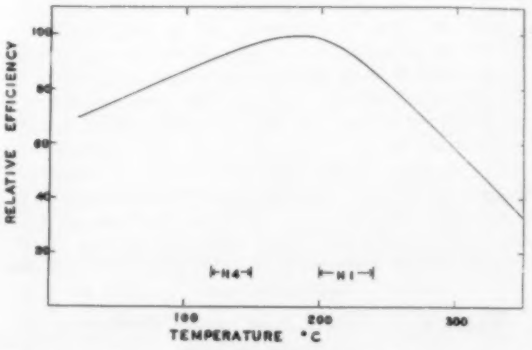


Figure 5. Temperature dependence of fluorescence of Strontium Zinc Phosphate.

TABLE III.

A. CLEAR MERCURY LAMPS

Designation	Lumens	Watts	lpw
LH4	3,300	100	33.0
AH22	6,800	175	39.0
EH1	21,000	400	52.5

B. LAMPS WITH GERMANATE PHOSPHOR

Designation	Lumens	Watts	lpw
MH4	3,000	100	30.0
BH22	6,000	175	34.3
JH1	20,500	400	51.2
KCH1	20,500	400	51.2

C. LAMPS WITH PHOSPHATE PHOSPHOR

Lamp Designation	Bulb	Rated Life in Hours	Lumens	lpw	% Gain in Lumens vs. Germanate
SH4	PS25	6,000	4,000	40	33
SH22	PS30	6,000	7,700	44	28
SH1	BT37	7,000	23,000	57.5	12
KSH1	R57	7,000	23,000	57.5	12

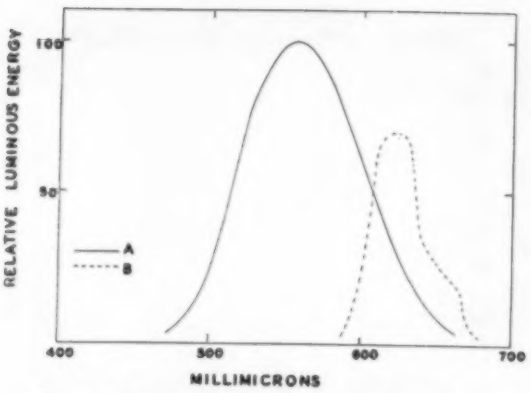


Figure 7. Relative luminous energy distribution of phosphor emission.
A. Strontium Zinc Phosphate in SH1 lamp.
B. Magnesium Germanate in JH1 lamp.

output and to the red rendition. This improved lumen output necessarily results in improved red rendition and no compromise is required.

Previous figures presented the emission spectra on a very compressed scale. It is of interest to use a more expanded scale for making a direct comparison of the characteristics of the JH1 and SH1 lamps from the standpoint of color rendition and lumen output. Fig. 6 shows the spectral distribution of the radiant energy for the fluorescent light emitted by the present SH1 and JH1 lamps. The total energy output of fluorescent light, shown by the area under the curves, is approximately equal for the two different phosphors. If, however, a comparison of the lumen output is desired, the energy at each wavelength must be multiplied by the luminosity function and thus another curve may be plotted to give the spectral distribution of the luminous energy (Fig. 7). It is apparent that the area under the SH curve is several times that under the JH curve, so the output of luminous energy is substantially greater.

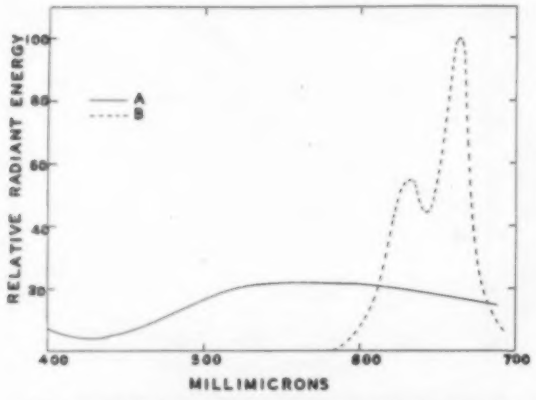


Figure 6. Relative radiant energy distribution of phosphor emission.
A. Strontium Zinc Phosphate in SH1 lamp.
B. Magnesium Germanate in JH1 lamp.

Colored Mercury Lamps

In a number of applications which will be mentioned in a following section, a high intensity source of colored light would be very useful. The HPMV lamp with an orthophosphate phosphor allows production of certain lamps of this type by use of a ceramic filter coat on the outside of the lamp jacket. The broad fluorescent emission curve of the phosphor allows a considerable range of colors to be made with varying degrees of efficiency. Experimentally, these have included blue, green, yellow and red. The lamp having the highest light output among the possible colors is that with a filter coating of a transparent yellow. This has recently been introduced as a 400-watt lamp with a BT37 bulb, the designation being GH1. The light emitted is a golden yellow of distinctive hue, which is in striking contrast to bluish white of clear EH1 lamps or the silver white of SH1 lamps. Color rendition is naturally distorted but yellows, oranges and reds have nearly their normal appearance. Further developments in the filter coated lamps will undoubtedly lead to the introduction of other colors in the near future.

Applications

The new SH and GH lamps, like all HPMV lamps, have a wide variety of uses where maximum

light output is wanted in a concentrated source. For high bay industrial lighting the improved color rendition and higher lumen output of the SH lamp compared to the clear EH lamps, combined with the diffusion effect of the phosphor coat give a useful low glare source, which is at the same time compact and long lasting. It is no longer necessary to sacrifice lumens for color.

Street lighting by HPMV lamps has been growing by leaps and bounds in city after city. In shopping and heavy traffic areas where quality of light is important the SH lamp can be used effectively in present fixtures. On residential streets, the improved color, increased lumen output and reduction of glare with the 100- and 175-watt SH4 and SH22 lamps will make mercury lighting considerably more acceptable than in the past. It should be noted that, in these sizes particularly, the phosphor coating helps to direct the light downward toward the street thus aiding the fixture designer. For arterial lighting, where control of light is of paramount importance, new fixture designs will be needed before the higher output SH lamps can be efficiently used.

The golden color of light from the GH1 lamp gives a new opportunity to street lighting and safety officials in that it provides a unique color at high efficiency which can be put to use at critical locations such as railroad crossings and highway intersections. The color contrast with other mercury lighting automatically suggests caution without appreciable loss of light. It is also noteworthy that a change from the blue white of clear EH1 lamps to the golden color of GH1 lamps does not require special fixtures but can be realized in minutes simply by a change of lamps.

For general outdoor lighting the increased lumen output of the SH lamps can be readily utilized, while in parking lot lighting, the broad emission spectrum minimizes distortion of all colors and thus speeds recogniton of cars by their owners. A more specific application is found in the floodlighting of buildings where unusual effects can be created by combining the silver white color of the SH lamp with the golden color of the GH lamp.

Future Developments

While the orthophosphate phosphors introduce a new concept in HPMV lamps, namely the use of phosphors to give more lumen output rather than the older concept of phosphors solely for color improvement, it is safe to say that they are only the first steps along this new path, and further gains can be attained when the phosphor chemist meets the challenge of developing new materials.

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DISCUSSION

LUKE THORINGTON:* The authors are to be commended for their notable addition to the growing list of phosphors which are useful under the stringent conditions existing in the high pressure mercury vapor lamp. Although the claim to novelty for a fluorescent mercury lamp of higher luminous efficiency than the corresponding clear lamp can not be justified in view of their Reference 9 and U. S. Pat. No. 2,748,303, they certainly are deserving of credit for extending this improvement to the highest degree yet attained. They are also to be commended for their novel use of optical filters with the HPMV lamps to provide sources of varying hue for use in certain special applications.

Among the several points I should like to discuss in greater detail is the statement by the authors to the effect that the magnesium germanate originally reported by Leverenz (Reference 7) was the first material used in color improved HPMV lamps in this country. Actually the material reported by Leverenz is practically dead by all standards of lamp phosphors and has never been used in HPMV lamps. It was not until Williams[1,2,3] (and not Kroger as indicated by the authors) discovered the effect of unusually large additions of MgO that this phosphor became significant as a photoluminescent material. Even then, however, its unusual properties which made it uniquely suited for the application at hand were not recognized. These properties were later described in detail (Reference 9) along with an additional improvement which doubles the phosphor efficiency and made possible the first really practical color improved HPMV lamp. Thus the first such practical lamps in this country[4] (and in the world) utilized the double-orthomagnesium fluorogermanate rather than the material indicated by the authors.

With respect to the advantages of the S-H1 over the J-H1, they are the same as the advantages of the standard cool white fluorescent lamp over the super de luxe cool white fluorescent lamp, *viz.*, that a higher lumen output is obtained at the expense of color rendition in the red spectral range. While the latter may not be so evident from data presented it becomes clear when one compares the per cent of energy in the (C.I.E.) eight spectral bands for the two sources as shown in the accompanying table. Data on the E-H1 are included along with those for the warm white de luxe fluorescent lamps as the latter compares strikingly with the J-H1.

The S-H1 is seen to have a distinct advantage over the E-H1 with respect to the relative energy in bands #7 and #8

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Spectral Band Data (Per Cent Energy)

Band No.	Spectral Range	E-H1	S-H1*	J-H1	Warm White De Luxe Fluorescent Lamp
1	-420	10.7	8.6	3.6	3.5
2	420-440	22.3	17.0	8.2	9.1
3	440-460	1.2	1.3	0.8	0.7
4	460-510	4.6	3.2	3.3	3.5
5	510-560	25.6	27.9	18.2	20.9
6	560-610	27.9	29.1	19.4	25.7
7	610-660	5.3	7.6	26.9	27.5
8	660-	2.4	5.3	19.6	9.1

*Data obtained from Sylvania Engineering Bulletin No. 0-178, March 1, 1956.

and also is seen to have relatively more energy in the more luminous portions of the spectrum (bands #5 and #6) than the E-H1. This is further borne out by the higher measured lumen output of the S-H1 (23,000 compared to 21,000 for the E-H1) and the higher per cent red lumens (5 per cent compared with about 1 per cent for the E-H1). By way of comparison the J-H1 emits 20,500 lumens with about 9-10 per cent in the red spectral region.

The authors have stated in the text and illustrated in Fig. 6 that the total fluorescence energy emitted by the S-H1 and J-H1 lamps is about the same. However, if one allows the 15 per cent loss associated with any such coating (as suggested by the authors) it can then be shown from their data that the phosphor in the S-H1 produces a total of 5150 lumens compared with 2650 lumens for the phosphor in the J-H1 lamp. From the luminosity factors of the respective phosphor spectra (.43 for the S-H1 phosphor and .13 for the J-H1 phosphor) it can be shown that the total energy emitted by the fluorogermanate is 30 watts compared to 17.6 watts for the phosphate. It thus appears that the new phosphor emits little better than half the energy emitted by the fluorogermanate in the H1 lamp but because of its higher luminosity emits almost twice as many lumens.

With further reference to the figures supplied by the authors I should like to point out an apparent major discrepancy between the spectral distribution data of Figs. 4 and 6 for presumably the same phosphate phosphor. Also, since the authors have pointed out that the strontium zinc phosphate: Sn fluoresces different colors depending upon the wavelength of excitation, I am caused to wonder for what emission band the excitation curve of Fig. 4 was obtained. Likewise for what excitation wavelength was the curve of temperature dependence of luminescence (Fig. 5) obtained?

Table III B contains data on HPMV lamps with "germanate" phosphor. Is this the fluorogermanate phosphor?

Finally it can be said that the use of narrow band emitting phosphors properly located in the spectrum would seem to be more desirable than the use of broad band emitting phosphors in the overall color correction of the HPMV lamps. Otherwise one ends up adding energy where already there is an excess (with respect to color rendition). Accordingly the ideal color improved HPMV lamp would utilize a narrow band emitting phosphor peaked in the orange-red and one peaked in the blue-green. Where maximum lumens are desired a green-yellow emitting phosphor would be used; for such a case I have calculated that an efficiency near 87 lumens per watt should be practically attainable for the H1 lamp. The authors have advanced the cause of mercury lighting by providing a phosphor which makes possible a lamp in the region between one of almost maximum red rendition and one of the highest luminous efficiency. For this they deserve and have our admiration.

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E. E. KADUK:* We believe with the authors that the light output added to quartz mercury vapor lamps by the use of a phosphor, along with partial color correction, represents a definite forward step in mercury lamp technology. However, there are several details of the paper on which we have questions and comments.

Regarding the reported gain in light output for the new phosphor, our preliminary tests indicate that the gain is at least partly offset by poorer lumen maintenance, so that the new lamp may be only the same as or poorer than the germanate lamp for mean lumens averaged over the life of the lamp. Can the authors offer any data on lumen maintenance relative to this question?

In Fig. 5 of the paper, the authors show the 400-watt quartz lamp jacket temperatures as 200-240C, a temperature range close to peak efficiency for their new phosphor. Our results show a bulb-wall temperature from 250C on the bottom to 350C on the top of lamps operated horizontally in a fixture, so that the average is considerably higher than the optimum temperature shown in Fig. 5.

The paper infers that there is a serious loss in light output and efficiency when the present color-correcting germanate phosphor is used with mercury lamps. Ratings shown in Table III give 20,500 lumens for the germanate coated lamps *vs* 21,000 for the clear lamp — a loss of only 2½ per cent. We would call this a relatively small loss for the degree of color improvement achieved.

The paper gives the impression that the color improvement with the new phosphor is substantially as good as with the germanate. We think that there is a considerable difference in the degree of color improvement, as is indicated by the relative energy in the red as measured through a Wratten #25 filter. The table shows the relative red energy from 400-watt quartz mercury lamps for the two phosphors and without phosphor.

Red Radiation from 400-watt Lamps

Phosphor	Relative Red Energy
None	1.6
Orthophosphate	3.2
Germanate	8.2

These figures which agree closely with the relative energy in the red for the two phosphors as shown in Fig. 6 of the paper, indicate that the new phosphor gives only about half the color correction of the germanate. These figures also agree with the visual impression in comparing colored objects under the three sources. The relative luminous energy as shown in Fig. 7 can be misleading in regard to color rendition, since only relatively few lumens in the red are needed to give a marked color effect.

No mention is made in the paper concerning the presence of aluminum as a constituent of the new phosphor, but it is our understanding that some aluminum may be present. Can the authors tell us whether aluminum is purposely included, and if so what its function is?

The paper mentions that the new yellow mercury (G-H1) lamp furnishes its special color without appreciable loss of light. Our measurements indicate that the loss of light is

*Large Lamp Dept., General Electric Co., Cleveland, Ohio.

about 25 per cent, a serious drop. Even with this loss, the color is not a highly saturated yellow, and a further loss is incurred for stronger color.

FRANCIS D. WYATT:* This paper reports further progress in the steady advancement made in mercury lamps which has been apparent since the end of the war in 1946.

It relates the progress made to date and reports new gains in color control and lumen efficiency which are accomplished and points out the possibility of further improvement.

It is most gratifying to learn that lumen efficiencies of nearly 60 lumens per watt have been accomplished for the S-H1 lamp and that ratings of 80 to 90 lumens per watt are within the realms of possibility.

It would be fitting at this time to note that with the low pressure fluorescent lamp reaching outputs of 1600 and 2500 lumens per linear foot, and with the possibilities of reaching the efficiencies given above on high pressure fluorescent lamps, that the art of street lighting is due for considerable advancement and refinement. The shorter low pressure lamps possible will permit smaller luminaires with much improved optical characteristics, and we hope, better overall efficiencies and lower cost. The same comment would also apply to the high pressure fluorescent lamp.

It would appear that we are reaching the end of an era which required a large ungainly fixture in order to take advantage of the benefits of fluorescent lamps. It would also appear that in the not too distant future the price of fluorescent street lighting can approach the present lower cost of straight mercury street lighting.

We wish to commend the authors for this report of progress and wish them well in further developments.

K. H. BUTLER:** Mr. Thorington has raised a point with respect to references to earlier work on phosphors. For the sake of brevity we used selected references, which were felt to describe the phosphors most effectively rather than attempting to give a complete bibliography.

While U. S. Patent 2,748,303 does claim improved lumen output for lamps made with magnesium fluogermanate phosphor coatings, it will be found that the lumen ratings of the coated lamps are invariably lower than those of clear lamps in all manufacturers catalogs. Table III shows this comparison. The fluogermanate phosphor was used in lamps listed in Section B of this table and has been used commercially as Mr. Thorington points out. With this phosphor, all of the ultraviolet is utilized and it may emit more *watts* of visible energy than the orthophosphate phosphor which uses only a part of the ultraviolet. However, we would like to emphasize again that the orthophosphate emits considerably more *lumens*.

The temperature dependence data of Fig. 5 were obtained using the arc tube of a 100-watt HPMV as the exciting source and thus it approximates the behavior in a lamp. Mr. Kaduk has reported some temperature data for a lamp in a fixture. These figures will vary considerably with fixture design and we anticipate that the lamp will be considerably cooler in a fixture correctly designed for control of light from the phosphor-coated emitting surface than it is when the lamp is used in a fixture intended for control of light from a clear lamp. Even with an ambient temperature of 250C (482F) the S-H1 lamp gives more lumen output than a J-H1 lamp.

With reference to maintenance, we did have some difficulties with early production of the S-H1 lamps and Mr. Kaduk's results were probably obtained on such lamps. At present, the lumen maintenance curve of S-H1 lamps is parallel to and somewhat above that of E-H1 and J-H1 lamps with 18,000 to 19,000 lumens being obtained at 1000 hours.

The moderate difference between the curves of Figs. 4 and 6 is due to difference in excitation. Data for Fig. 4 were obtained with the excitation radiometer using an exciting wavelength of 280 millimicrons while the data of Fig. 6 were derived from the emission curve on a 400-watt S-H1 lamp. The excitation band of Fig. 4 was measured for emission at 600 millimicrons.

Mr. Kaduk has confused hue and saturation in his comments on the G-H1 lamp. Our measurements give $\bar{x} = .443$, $\bar{y} = .543$, $\bar{z} = .016$ which is a highly saturated color. The hue is yellow rather than orange and this is probably what Mr. Kudak had in mind. If a clear mercury lamp is replaced by any single source of yellow light other than the G-H1 lamp the loss of light is extremely severe and, with this standard of comparison, it can be said that the G-H1 lamp gives excellent lumen output.

Both Mr. Kaduk and Mr. Thorington stress, though with appreciable difference in their numerical values, the lower red output of the S-H1 lamp as compared to the J-H1 lamp. This is, we feel, an over-emphasis on a single aspect of color improvement. Color rendition of *red* is not the only point to be considered. Rendition of yellows, oranges, greens and blue is also important. This would not be realized with the narrow bands of emission suggested by Mr. Thorington.

Even in the S-H1 lamp 75 per cent of the lumens come from the intense green and yellow lines of the mercury are in contrast to the 10 per cent contribution of the mercury lines in fluorescent lamps. Because of this predominance of green and yellow, color rendition with HPMV lamps is far inferior to that with fluorescent lamps. So, if color is *vital*, the user should consider the VHO lamp rather than any HPMV lamp.

The main advantage of the phosphate phosphor lies in its contribution to lumen output, with the improved color being an added attraction. As new phosphors are developed with greater lumen output they will probably be used at once, since a major virtue of the HPMV lamp is the concentration of a tremendous number of lumens in a relatively small source. We are glad to see that Mr. Thorington's estimate of 87 lpw, or a possible 66 per cent gain in light output from the H1 lamp, gives as optimistic a goal as our own estimate of the ultimate performance of phosphor coated HPMV lamps.

*Electrical Engineer, Elmhurst, Ill.
**Co-author.

Statistics

Length of avenue	1.9 km (1.18 miles)
Width — total between building fronts	70 m (230 feet)
Width of automobile roadway	28 m (92 feet)
Width of each sidewalk	21 m (69 feet)
Spacing of old gas units	10 m (33 feet)
Spacing of new units	22 to 28 m (72 to 92 feet)*
Height of new units	8½ m (27½ feet)

*Some variation in spacing due to locations of trees.

Re-Lighting the

CHAMPS ELYSÉES

After nearly a century, the famous and beautiful Avenue des Champs Elysées in Paris was, last year, re-lighted for today's traffic conditions. The previous gas lighting system which had, with modifications, been in use since 1859 has been replaced by an installation using color-corrected mercury and incandescent lamps.

Aesthetic considerations were of paramount importance in the selection of luminaires and sources, and the chosen design was subject to restrictions by the Commission des Sites et les Services d'Architecture de la Ville. Also, the existing gas lighting units were to be retained, as part of the traditional scenery.

After discussion and experiment by the Services Techniques de la Ville de Paris, decision was made for a hemispherical lamp housing using a combination of color-corrected mercury and incandescent lamps, on a fluted steel standard with two curved arms. The pole and arms have a bronze finish.

Housings on the street side have one 250-watt (10,000-lumen) mercury lamp and one 500-watt (9,000-lumen) incandescent lamp; those on the sidewalk side have one 125-watt mercury and one 300-watt incandescent. The old gas lanterns have been converted with one low-wattage mercury lamp and an incandescent. These are mainly decorative.

Illumination level with the new installation is 2 footcandles, as compared with the former 0.1 footcandle with the gas lighting system.

Control equipment for each of the new fixtures is contained in the base of each standard, which also holds the controls for nearby converted fixtures.

Photographs courtesy of Saunier Duval, Paris, France.

EFAS-A New and Vital Aid To Low Visibility Landings by Aircraft

By DONALD I. COGGINS

THIS PAPER describes the operation and function of the Electronic Flash Approach System (EFAS) as a key component of the integrated Aircraft Visual Landing System evolved by the Civil Aeronautics Administration, Air Transport Association, Air Line Pilots Association, and participating lighting manufacturers. The success of low visibility landings may be related directly to the timeliness and spontaneity of the transition from Instrument to Visual flight during approach and the degree to which the necessary aids provide the required information and guidance without loss of eye sensitivity. EFAS contributes the essential ingredients to accomplish these objectives and in combination with other more conventional light sources arranged in a unique configuration and radio approach aids provides a complete solution to landing of aircraft under low visibility conditions.

The Urgency for Improved Traffic Control

One needs only to observe air traffic figures at any of our major airports to appreciate the rapid and serious congestion of planes — a condition which becomes manifoldly desperate when weather necessitates instrument flight rules.

At Chicago's Midway Airport, for instance, the total annual plane movements (landing and take-off) in 1945 were 153,007 carrying 1,496,634 passengers. During 1950 the corresponding figures were 234,331 and 3,820,165. By 1955 plane movements reached 381,005 with 9,134,503 total passengers, an increase of some 150 per cent in plane traffic and better than 500 per cent in passenger traffic in a span of ten years.

It becomes clearly apparent that a rapidly growing segment of the American public and business is more and more frequently dependent directly or indirectly on air transportation. Delays and diversions which a few years ago were of only localized importance now become major problems and inconveniences.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 17-21, 1956, Boston, Mass. AUTHOR: Sylvania Electric Products Inc., Salem, Mass.

While flight continuity and adherence to destination and time schedule are important to the customer, they represent distinct financial benefit to the municipalities and airlines involved. With the industry facing unlimited growth prospects, the Airlines and C.A.A. face a major task and responsibility in controlling the movement of an ever-growing number of faster and larger planes in such a manner as to assure the continuation of high standards of safety.

Historical Background of Development Of Visual Landing Aids

The study and evaluation of single-row visual approach systems equipped with sequential flashing condenser discharge units was first undertaken in this country in the middle 1940's. The All-Weather flying group of the Air Transport Command headed by Lt. Col. E. A. Cutrell (now Captain Cutrell, American Airlines) and the U. S. Navy Bureau of Aeronautics figured prominently in this project along with lighting equipment manufacturers.

Perhaps one of the most scholarly and basically sound theoretical studies of the fundamental requirements of visual aids was made by E. S. Calvert,[1] a prominent and respected lighting engineer from England. Time has proven the validity of many of his conclusions.

In subsequent years the Air Transport Association of America, the Civil Aeronautics Authority and the Airline Pilot's Association all played an active role in the development of today's integrated approach lighting system.

The Fundamental Requirements Of Low Visibility Visual Landing Aids

Since runway lights are completely obliterated from view during the early stages of approaches in low visibility weather, a pilot passing through the radio approach pattern of the Instrument Landing System (ILS) must transit from full instrument to full visual flight and finally complete his landing by reference to the runway lighting. The transition from full instrument flight in the radio pattern to

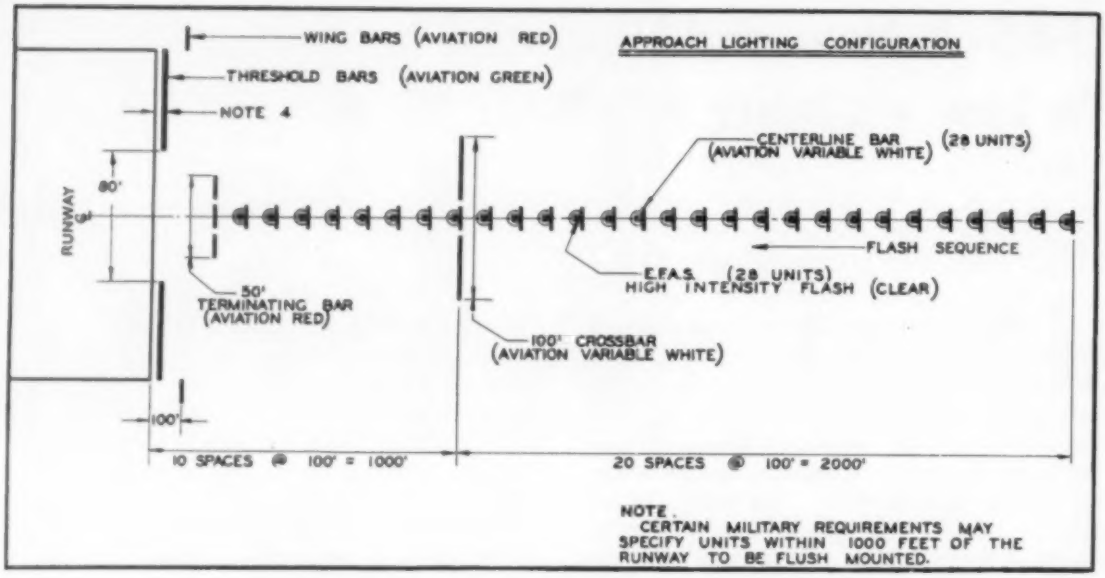
APPROACH LIGHTING CONFIGURATION
WING BARS (AVIATION RED)
THRESHOLD BARS (AVIATION GREEN)
NOTE 4
CENTERLINE BAR (AVIATION VARIABLE WHITE) (28 UNITS)
80'
RUNWAY
FLASH SEQUENCE
E.F.A.S. (28 UNITS) HIGH INTENSITY FLASH (CLEAR)
50' TERMINATING BAR (AVIATION RED)
100' CROSSBAR (AVIATION VARIABLE WHITE)
100'
10 SPACES @ 100' = 1000'
20 SPACES @ 100' = 2000'
NOTE.
CERTAIN MILITARY REQUIREMENTS MAY SPECIFY UNITS WITHIN 1000 FEET OF THE RUNWAY TO BE FLUSH MOUNTED.

Figure 1. Complete approach lighting system with EFAS.

the required full visual flight normally begins approximately 3500 feet from the runway when the aircraft is within 200 feet of the ground. Between here and a point approximately 1000 feet from the end of the runway, when the aircraft is down to within 80 feet of the ground, visual aids must take over and thereafter provide positive and absolute guidance down to the runway threshold.

Clearly the heart of any system rests with the transitional phase which is supplied by EFAS as described later.

The objective system, therefore, was hypothecated on a set of very special and demanding requirements for visual aids which during low visibility weather, day or night, would provide a pilot with the following information:

(a) Early and positive identification
(b) Absolute line and directional guidance
(c) Roll guidance or horizon information
(d) Distance information
(e) Height reference
(f) Termination of approach lights
(g) Location of runway threshold
(h) Runway guidance.

Description of Recommended Centerline Visual Approach System

Fig. 1 shows the system evolved through several years of study, design and operational testing. The system is essentially a single centerline of 28 flashing lights and 28 steady burning bar lights extending out 3000 feet in front of the runway. The development of lighting sources and configurations has been based upon sound practicality with each element serving a definite function.

Two distinct forms of lighting are employed in a total of three variations. For needed ultra-high intensities, great conspicuity and absolute directional guidance, sequentially-flashing condenser discharge EFAS lighting units are employed. To provide horizon, stable fix orderly transfer from full instrument to visual flight and to serve as position markers, PAR 56 sealed-beam incandescent lamps are used in multiple bar configuration. These incandescent lighting units are of two colors for reasons to be explained later.

The EFAS condenser discharge units are arranged to flash in rapid sequence towards the runway in ½-second cycles, giving the effect of a white hot ball streaking in at a speed of some 3600 mph.

In the following a detailed description of each component part of the system and its function will be given.

Description of EFAS Condenser Discharge Lighting Units

The condenser discharge (EFAS) units, shown in Fig. 2, employ a novel yet not new principle for producing vivid, short duration flashes of blue-white light. In order to develop a large amount of light energy in a very short space interval of time, electrical energy is stored in a capacitor. In this case a capacitor is charged with about 60 watt-sec-

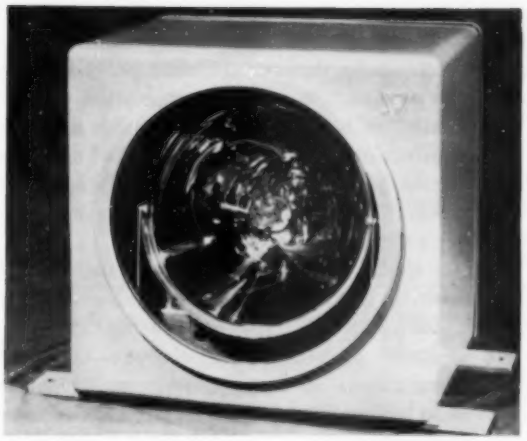

Figure 2. Typical EFAS condenser discharge light unit.

onds of energy which when converted to light is equivalent to approximately 1800 lumen seconds compressed into a time interval of but 5/10,000 second. Under these conditions the peak output of these units reached 30 million beam candlepower.

An excellent article has been recently written on condenser discharge tube efficiency by Professor Harold E. Edgerton[2] of M.I.T. and others.

The means for attaining this flash energy is conventional. Alternating current is converted to direct current through a full-wave vacuum tube rectifier circuit which in turn charges a storage capacitor to some 2000 volts.

The flash tube is a spiral coil of Pyrex tubing measuring approximately 2½ inches in diameter and coil length. The tube is filled with xenon gas and has an anode, cathode and external trigger wire. This tube is connected directly across the charged condenser. It is so designed that it will not conduct current with anode voltage applied unless externally triggered. When, however, an ignition voltage in the order of 10,000 volts is applied to the trigger wire, the gas within the tube is sufficiently ionized to cause immediate conduction of current, instantly discharging the condenser and producing a brilliant burst of light.

Proper and accurate sequencing of each condenser discharge unit is attained by a central Master Sequence Timer. This unit energizes a relay in each EFAS unit which in turn applies a triggering impulse to its associated flash tube.

For reasons to be explained later, certain unique characteristics of these flash units which are major factors in the success of the overall system should be enumerated. The color of the flash is a distinctive xenon blue-white. The duration of flash is but a few hundred microseconds allowing long relative "off" periods between flashes. As a result, supersonic speeds of travel of the flash along the approach line are possible without "tailing." Enormous instantaneous light energy is developed to offset the long "off period." Beam spread to the 50 per cent intensity point is 25 degrees while the flash tube is directly visible over an angle as wide as 120 degrees.

Description of Typical Bar Type Incandescent Units

Reference to Fig. 3 will show the typical bar unit made up of five sealed-beam lamps. The basic centerline unit measures 14 feet in length. Maximum candle output of each lighting unit is 30,000 and is controllable over a wide range. The horizontal beam width of these lighting units is approximately 20°, while vertical beam spread is approximately 10°, both to the ½ intensity point.

Identification of System and Transition from Instrument to Visual Flight

A key component of the visual approach system is the line of condenser discharge flashing units which first catches the eye of the pilot and provides instant and instinctive recognition.

The great conspicuity of condenser discharge lighting units results from high fog penetration, dynamic eye attraction, rapid unidirectional movement and non-blinding qualities.

The 30-million beam candlepower developed at the peak of the flash provides a total of integrated

Figure 3. Typical PAR 56 sealed beam bar unit.

light during the few hundred microseconds of "on" time sufficient to pierce heavy fog.

The brilliant and characteristic blue-white flash renders an unmistakable identification, particularly as it resembles a tracer bullet. Under the most severe atmospheric conditions occurring during daylight hours, a light source assumes a double burden. First it must predominate over the background illumination. Second it must be easily located. A flashing source has a distinct advantage by virtue of its on-off sequence in distinguishing small differences in brightness. In photometric work, whereas two adjacent spots of nearly equal brightness are almost indetectable in the steady state, they become quite obvious when one is alternately turned on and off.

During low-visibility night approaches one must exercise extreme care to prevent blinding and glare. Mr. Calvert raised this note of caution and suggested dimming of steady-burning lights to suit the atmospheric conditions. To an amazing degree the intense but extremely short duration flashes of the condenser discharge units cause no blinding for illumination nor does the eye experience any loss of dark adaptation so important for picking up the lower intensity runway lights. This fact is supported by studies made by an independent laboratory. For this reason no sacrifice of fog penetrating qualities need ever be made with condenser discharge lighting.

Because of the possibility of human as well as instrument error during radio approaches and the need for circling guidance in some instances, the condenser discharge lights provide a wide angle beam.

Line and Directional Guidance

Once established over the approach line of lights, a pilot must next receive directional guidance. This sort of information is quickly and positively obtained from the EFAS condenser discharge units whose rapid fire sequence towards the runway leaves no room for doubt.

Additionally the line of steady burning bar lights provides a definite line fix. It has long been recognized that small spot sources or flashing lights do not provide optimum line guidance by themselves.

During low-visibility approaches these steady burning bar units must be substantially reduced in intensity to prevent serious fog glare, as previously indicated.

Roll Guidance

With fog obscuring the natural horizon a pilot must depend upon artificial visual aids to provide such information. Because either incorrect attitude or lateral displacement from true centerline approach frequently presents the same perspective to a pilot in a point light source configuration, the implementation of bar units to the system is an absolute requirement. By giving dimensions of a known value to the bar units a pilot can quickly spot roll and differentiate it from lateral displacement and properly correct his approach.

Unlike the American EFAS system the Calvert configuration utilizes bar units placed every 600 feet in contrast to our 100-foot spacing. Observation of filmed approaches and accounts of pilot's actual experience with the Calvert configuration lead us to believe that during very low visibilities, roll guidance is absent for too long a period of time and lacks continuity desirable for smooth corrective action.

Distance Information

In following a single line configuration a pilot upon passing over the 1000-foot bar marker, shown in Fig. 1, immediately and unmistakably (since there is but one clear elongated bar in the system) recognizes his distance from the runway.

This marker also assumes the nature of a commitment point where a pilot decides either to complete a landing or, for some reason, to initiate a missed approach procedure.

In this phase of the approach configuration the American system again differs from the Calvert proposals. Distance from the runway is indicated in the latter case by seven transverse bars of constantly diminishing length spaced 600 feet apart.

It is the opinion of many pilots in this country that too much interpretative effort is required of the Calvert multiple bar configuration. In addition there is no positive means of recognizing the last bar unit. The existence of but one clear extended transverse cross bar of the American system is simplicity indeed.

Height Reference

The pilot flying over this centerline approach system derives height reference from two physical elements of the configuration. First is the apparent length of the 14-foot bar units and second the apparent distance between successive units standardized at 100 feet.

A novel feature of the Calvert system is the use of the varying cross bar lengths as described above. A perfect approach would cause all bars to appear the same length. If bars appear to decrease in length the approach is too high and vice versa. The opinion in this country appears to treat this feature

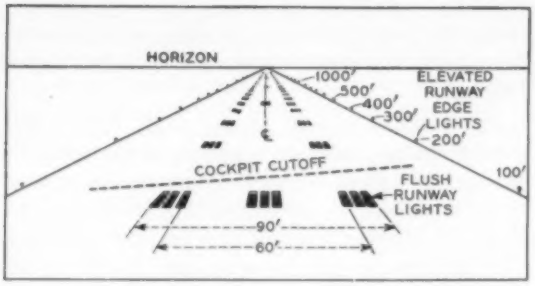

Figure 4. Proposed narrow gauge flush runway lights.

as necessitating severe interpretative effort since low visibilities can play dangerous tricks on point to point comparisons of bar length. The Calvert system also requires multiple elongated bars negating the value of the single distance bar used here. It is believed that height information is quite adequate without this refinement if not complication.

Termination of Approach Lights and Runway Imminence

At a distance of 200 feet from the runway is placed an extended red warning bar indicating the end of the approach light line and warning of the immediate imminence of the runway.

At a distance of 100 feet from the runway are placed two 14-foot red wing bars outlining the absolute lateral limits for safe landing.

Both of these facilities are shown in Fig. 1.

Runway Threshold

Within approximately 25 feet of the landing surface are placed the green threshold lights. Actually they consist of two bars, separated by an 80-foot clear space for landing, extending laterally to the line of runway lights on either side giving clearance to touchdown.

Runway Guidance

At present a plane letting down on the runway surface generally relies upon the parallel rows of runway edge lights.

To a pilot who has been following a clearly-defined single row of lights, the sudden transition to parallel rows of runway lights quite outside his normal angular visual range, resembles flying into a "black hole."

To explain the causes and effects of this phenomenon is to delve into the complexities of foveal and parafoveal vision. An excellent treatment of this has been made by A. E. Jenks[3] of the Civil Aeronautics Administration.

It is of interest that because of this "black hole" effect, made more serious by the normal action of a pilot's eyes to go into a "stare" condition during the final stage of approach, there is a critical need for improved runway lighting. At this time emphasis is being placed on a form of flush narrow gauge runway lights. Such lights would take the form of two parallel rows of 15-foot transverse bar lights separated by 60 feet as shown in Fig. 4.

The objective of such a system is to place the runway lights within the range of the acute foveal vision, thereby continuing roll guidance onto the runway and marking, by the passage from single to double row, the beginning of the runway area.

Operational History

No system of approach lighting is a success merely on paper. The evolution of the integrated system described above has been marked by study, trial, elimination, addition and final standardization.

The use of the EFAS lighting dates back several years and was found to be not only sound but extremely necessary adjunct to an approach lighting system.

The use of a single centerline configuration came after a great deal of study, discussion and testing. Previously tried were such configurations as parallel side rows of lights, converging rows a single left hand row, and many others. Operating pilots in this country are firmly convinced that greatest simplicity, a minimum of interpretation and optimum guidance is provided by a single centerline row of lights.

At Newark the EFAS type system has been in operation for several years. For the past five years it has been a centerline configuration, where previously it was a left hand row.

At Idlewild the system has been in operation since the first of last year, where it is meeting with exceptionally high compliments and most effective operational assistance.

Both airports are considered models of approach light efficiency and effectiveness — both here and abroad.

Need for Standardization

The ultimate success of visual approach aids rests not only with a sound system but in standardization over as wide an operational area as possible.

Pilots should quickly come to know precisely what the system looks like on the ground as well as

from the air. They should be aware of the physical size of the component parts of the system that they may judge the apparent size and shape from the air and thereby gain valuable information regarding altitude, lateral position and speed.

A concerted effort is being made by the Civil Aeronautics Administration in this country to effect standardization. There probably must be some variations due to local terrain conditions, as for instance the limited approach area as found here at Boston. However, every effort should be made to avoid variations and departures from standard. There are few if any cases where the obstacles to standardization are unsurmountable and standardization cannot be maintained.

The approach lighting configuration employed at civil fields in Canada is very similar to our standard. Their bar lights although 20 feet in length fortunately appear to cause little visible alteration in the perspective from the air.

It is natural that we should look forward to even greater similarity between systems in other countries and those in the United States. The International Air Transport Association is doing a fine piece of work in this direction.

In Mr. Calvert's system the sequentially flashing units of EFAS are missing but could be very easily added. Some other variations such as the number of bar lights and their spacings are thought to be somewhat deficient in an otherwise good system.

Unfortunately transatlantic pilots today face the need of distinguishing different types of systems at the opposite ends of their runs. We can only hope that this situation can and will be corrected in the very near future, perhaps through the efforts of the International Air Transport Association.

The Future

The Civil Aeronautics Administration has a definite program calling for the early installation of complete and integrated EFAS-equipped approach light systems at many of the major airports of the country to match Newark and Idlewild.

It is the opinion of many that EFAS equipped approach lights should be installed and integrated with each and every instrument landing system now in operation, or as installed in the future. If traffic and weather conditions warrant radio approach aids, an airport is certainly entitled to a visual approach system to fill the 3,000-foot gap to the runway.

It is superfluous to repeat, but would be vitally negligent not to re-emphasize, the glaring fact that the loss of lives and plane in just one approach accident attributable in whole or part to lack of adequate visual aids would pay for many installations. We cannot compromise safety with the coming of jets and much higher concentration of air traffic.

Our airlines as well as the Civil Aeronautics Administration are only too aware of the problems facing them. Both are working strenuously to meet today's demands for a complete Air Traffic Control. C.A.A. is currently sponsoring an admirable five-year program to provide what they consider absolute necessities for adequate air navigation. We must lend our support and backing to their efforts to insure that the necessary funds and priorities are forthcoming to shrink this five-year program timewise to a two- or three-year program.

References

1. Calvert, E. S.: "Visual Aids for Low Visibility Conditions," *Journal of the Royal Aeronautical Society*, 1948. Vol. 52, pp. 439-472.
2. Bird, Robert A., Miehe, Frederick W. and Edgerton, Harold E.: "Flashtube Efficiency," *Photographic Engineering*, 1956. Vol. 7, No. 1.
3. Jenks, A. E.: "The Black Hole," *The Airline Pilot*, April 1956.

DISCUSSION

F. C. BRECKENRIDGE:* Mr. Coggins is to be commended on having presented a paper descriptive of the new approach light installations which are being planned by the Civil Aeronautics Administration since this development has received practically no attention in the Society's publications. In order that the record may be clear, however, it seems well to add a brief comment regarding the relation of the sequence flashing lights to pilot guidance.

The sequence flashing lights as an aid by themselves were tested by the Landing Aids Experiment Station at Arcata, Calif., and after several approaches it was found that when this aid was used without fixed lights it was very dangerous so that this testing had to be discontinued. Tests were continued with a combination of sequence flashing lights with fixed lights and it was the conclusion at the end of the 1949 season that the sequence flashing principle contributed nothing to guidance except a discrimination between the inner and outer ends of the approachway. With modern methods of traffic control, it is probable that this discrimination is no longer needed. The sequence flashing lights do have greater conspicuity than fixed lights, especially when seen at a large angle to the direction of vision. They are also distinctive, which makes the approach light system easier to identify.

It is unfortunate that Mr. Coggins did not find space in his paper for a report on the circuitry which his company has developed for operating the sequence flashing lights. I understand that their new circuits have introduced a very important element of economy into both the original costs and prospective maintenance costs of the system. So long as the pilots continue to consider the conspicuity and identification provided by this system to be worthwhile, this improvement in economy is a very important one since the system is very expensive to manufacture in its original form.

*National Bureau of Standards, Washington, D. C.

C. A. DOUGLAS:* I will confine my comments to one question raised by Mr. Coggins' paper: namely, the applicability of the Blondel-Rey law to computations of the visual range of condenser discharge type lamps. We have checked the effective intensities and the visual ranges of flashing lights, including condenser discharge lamps on numerous occasions and have found no significant deviation from the Blondel-Rey law. All apparent deviations which we have analyzed have resulted from viewing narrow-beam incandescent-lamp projectors and condenser discharge lights from angles such that the observer is outside the beam of the incandescent unit, but within the beam of the wider beam condenser discharge unit, and using the intensity of the peak of the beam as the intensity of the incandescent projector. When the intensity in the *direction of view* is considered, there are no apparent discrepancies.

For example, a difference of from 5 to 15 seconds between the time of sighting the flashing lights at Newark Airport and the time of sighting the incandescent lights has been reported by pilots. Often this difference has been attributed to some deviation from the Blondel-Rey law. It is, however, simply a matter of intensity difference. The old 250-watt incandescent approach light lamps had a peak intensity of about 90,000 candles but these lamps had a very narrow vertical beam spread. The intensity directed toward an aircraft on the glide path by the outermost incandescent light 3000 feet from it was only 2500 candles and the intensity was only 1600 candles toward the position 5000 feet from the light.

Thus the pilot, though on the proper glide path, was in the stray light region of these lamps for most of his approach, but was within the main beam of the flashing lights. Computation of difference in sighting time, assuming an effective intensity of 15,000 candles for the flashing lights and the actual intensity of the incandescent lights, gives differences of 50 to 15 seconds in sighting time when the visibilities by day are ½ to 1½ miles, and 20 to 40 seconds under VFR conditions.

Newer installations of incandescent approach lights employ wider beam lamps, based on those developed for the Bureau of Aeronautics in 1951. With these wide-beam lamps, a pilot on the glide path will be within the main beam of these lights throughout the approach.

J. W. STRANGE:** My initial reaction after listening to this paper is to go out and cancel my air reservations.

Once again I am impressed, if not over-awed, by the difficulty of the pilot's task in landing an aircraft in foggy weather. In these circumstances any additional help that can be given to the pilot is valuable and this flashing line of lights has one very important characteristic. It does stand out in a very clear way from any random lights which may be apparent in the neighborhood of the airport.

My main criticisms of the systems are two. Reference has already been made to the limitation of any flashing system that it requires an appreciable time to convey its information and the split seconds that are available may often be inadequate. The other point is that the cross bars are very inadequate to provide the very essential horizon information and roll guidance. To my understanding of the problem these two items are far more vital than the general direction and centerline information provided by the flashing line of lights. It may be of interest to quote from *Transactions of Illuminating Engineering Society* (London), page 197, 1956. A statement made by Calvert recently is quoted there:

> "... our work on visual aids has paid very handsome dividends in safety, regularity of service, and airport utilisation. An example of this is the fact that in a visibility of half a mile the failure rate in first attempts to land is less than 8 per cent at London. In the United States the failure rate is usually over 30 per cent in this visibility, although it has improved recently because of the introduction of better instrumentation in the aircraft."

There seems no doubt that the basic principles of the Calvert system are sound. The greater realization of these principles in combination with the present EFAS proposals should yield an even higher degree of safety.

T. H. PROJECTOR:* I would like to discuss several very general aspects of the paper, having to do only with the properties of condenser-discharge lamps as such rather with the particular configuration and application described. The configuration is of considerable interest and may have merit of a very high order. However, such merit would derive from the configuration rather than from the alleged superiority of the condenser-discharge lamp as such. Lamps of this type have been used recently in a number of aviation applications, and along with this there has been a general tendency to proceed from the characteristics of these lamps, particularly extremely short duration and correspondingly high instantaneous intensities, to a free violation of the laws of thermodynamics and to a contradiction of the large body of research data relating to the visual aspects of the applications. Mr. Coggins, I am afraid, has been guilty of some of these sins, and I would like, therefore, to correct some of the mistaken notions, expressed or implied, that the paper contains.

First I would like to point out that condenser-discharge lamps share the virtues of flashing lamps in general. Their virtues in this respect, however, are the virtues determined by well-established relations, notably the Blondel-Rey law connecting effective intensity with the duration of the flash and the intensity-time distribution. Thus, in what follows, to the extent that I discount any special claims for these lamps, it is only insofar as more is claimed for them than is claimed for flashing lamps in general or insofar as it is suggested that in the flash duration region in which they operate, relations such as the Blondel-Rey are not applicable or must be modified.

The luminous efficiency of discharge lamps is of the order of 30 to 35 lumen-seconds per watt-second. Mr. Coggins has evidently used the figure of 30 lumen-seconds per watt-second since he reports 1800 lumen-seconds for an input of 60 watt-seconds. It should be kept in mind, however, that this is lamp efficiency and that the efficiency of the auxiliaries required to operate these lamps reduces the overall efficiency of installed systems to the order of 15 lumen-seconds per watt-second. This value is of the same order of magnitude as that of incandescent lamps.

Mr. Coggins describes the color of the flash as a "distinctive xenon blue-white." The blue-white color of the flash may or may not be the most desirable color for this configuration. If it is, it can easily be obtained with other sources, *e.g.*, with appropriate filters in front of incandescent sources, or, if it is not, then the color of the discharge lamps may be modified with filters. In any event the color of the discharge lamp is not unique or difficult to obtain, if

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**Thorn Electrical Industries, Enfield, Middlesex, England.

*National Bureau of Standards, Washington, D. C.

it is indeed the most desirable color for the application. Furthermore, it is generally recognized that the number of "distinctive" colors that may be used in navigation or signaling is quite limited. Under favorable conditions, the bluish white of the flash lamps might appear distinctively different from other whites, but under many important visual conditions such distinctions become very small and it may even be difficult to distinguish colors differing in chromaticity by amounts much greater than those that may occur between different whites.

Mr. Coggins refers to "high fog penetration" and to "nonblinding qualities" as special properties of condenser discharge lamps. There is no reliable evidence for special superiority in either of these respects.

Mr. Coggins say that: "The 30-million beam candlepower developed at the peak of the flash provides a total of integrated light during the few hundred microseconds of 'on' time sufficient to pierce heavy fog." The implications of this statement are unclear, but it does suggest that the very high instantaneous intensity is somehow more effective than lower intensities might be in piercing fog, even though the lower intensities might prevail for longer periods. There is no evidence to support this notion. All the research on the subject is in accord with the Blondel-Rey equation which equates in effectiveness any light flashes of equal energy — the product of intensity and time — at least until durations of the order of the critical duration, about 0.05 or 0.1 second, are reached. Other variables may affect the apparent intensity, *e.g.*, the level of illuminance at the eye, but the duration of the flash, as long as it is significantly less than the critical duration, does not, except insofar as it is involved in the energy content of the flash.

Mr. Coggins goes on to say: "To an amazing degree the intense but extremely short duration flashes of the condenser discharge units cause no blinding for illumination nor does the eye experience any loss of dark adaptation so important for picking up the lower intensity runway lights. This fact is supported by studies made by an independent laboratory. For this reason no sacrifice of fog penetrating qualities need ever be made with condenser discharge lighting."

Flashing lights in general are superior to steady burning lights of equal effective intensity in regard to freedom from glare and maintenance of dark adaptation. However, as noted before, condenser discharge lamps are not "amazingly" different or even just different from other flashing sources whose duration is below the critical duration, although well above that of the discharge lamp. For equal effective intensity, equal side effects are obtained.

To sum up then, the visual effects of condenser discharge lamps are those that would be expected from an application of the Blondel-Rey equation, and there is no evidence that the lamps have any properties especially attributable to the extreme shortness of the duration of the flash or to the extremely high instantaneous intensities reached other than those related to the energy in the flash.

To avoid any misunderstanding, I would like to point out that nothing I have said is intended to minimize the importance of the shortness of the duration in other respects where it may have valid applicability. For example, extremely short duration may help avoid "tailing," as Mr. Coggins has pointed out, and contribute to clean definition of the moving spot. Here again, however, in view of the persistence of vision appreciable increases in duration time might be allowed without noticeable increase in the tailing effect. It may very well be that the discharge lamp is the optimum source for this application but if this is so, I hope the superiority will be established on the basis of an objective analysis of the merits.

KEITH H. BUTLER:* It was not my intention, at all, to comment on this paper, but the question of scattering of light came up and that carried me back fifteen years to the time when I was working on pigments for paints. There the problem is essentially the same thing; to get hiding of the contrast between a black and white surface, you have to scatter the light. In the pigment business the method is to control the particle size of the pigment to give the maximum amount of scattering. With pigments which give you the maximum hiding power, *i.e.*, the maximum scatter for white light, you will get more scattering for blue light than you will for red, but if you change your particle size (I am going back fifteen years in memory) a slightly larger particle size, as I recall it, will scatter red more than blue. With regard to scattering of light by fog or haze, there is a wide variety in the particle sizes of the fog particles. If you have done an extensive amount of automobile driving, you know that the ground fogs that you get inland, which are generally small particle size, are much worse to drive in than sea fog which is large particle size. So that I think any discussion of the visibility of the light through fog should take into account the particle size of the drops. There has been a tremendous amount of work done in the last ten years on the relation between scattering and particle size, which is not known by many people working with lighting, but which has an important bearing on visibility.

EUGENE W. BEGGS:** It was a privilege to view the author's motion picture study of fog landings. While seeing the movies, I felt that I had come nearer to experiencing this problem than ever before. I have flown in fog seeking to know more about this thing, and I think today I got more out of the movie than in many actual landings.

I was going to ask two or three questions. One had to do with the relationship between brightness and dazzle in a flashing light and in a continuous light, and since others have asked the question, the author will probably discuss it fully. I do not believe there is a basic advantage in a flashing light because of this specific factor, and I would like to hear more from Mr. Coggins about it.

The other thought was that to me, viewing the movie and comparing it with my own experience, this effect of conspicuity (a good word) is perhaps the chief factor. Your eyes notice things that move, your eyes notice lights that flash, and particularly the side vision is very sensitive to both these phenomena. This is probably the real advantage of a flashing light system as was used in the installation at Idlewild and on the Berlin Airlift.

There is a further thought here that should be expressed. The system on the Airlift attempted to do the two jobs — one to bring the plane down close to the entrance end of the runway, and the other to lead it to the contact point. The EFAS system attempts only the first of these and from there an adequate system of fixed approach lights takes over. That is real progress and looks to me like a good system to develop and use.

M. E. KECK:† First of all, let me compliment Mr. Coggins on a fine summarization of the very involved and complex subject of approach lighting in a very short paper. One

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†Westinghouse Electric Corp., Cleveland, Ohio.

difficulty that he faced was the necessity to familiarize those in his audience and the readers of his paper with the overall problem of approach lighting before it was possible to discuss the one segment "electronic flash approach systems" which is the real title of his paper. I wish to point out the following facts in summary. First, that the electronic flash approach units are not a complete lighting system in themselves, but are a part of the overall approach lighting system. Flash units supply information to the pilot on only two of the items which the author lists in his paper:

(a) An early and positive recognition of the location of the previously invisible approach lights,

(b) Directional guidance to line up with the center of the runway so that he may continue his approach with assurance that additional lights with other information will soon come into view.

The flash units do not supply positive information on roll guidance, distance, height reference, etc. The second point is that the electronic flash approach units are not new in theory or manufacture. The thing that is new is that they have, we hope, passed the experimental stage and that their adoption by C.A.A. as a part of Configuration A means that they will soon see mass installation in use. Electronic flash units, not of the same design but similar, were shown to the I.E.S. in its Conference in 1946. A partial installation was installed at Cleveland Airport in 1946. A full installation was installed at Idlewild in 1947. The units were used as part of the approach system of the Berlin Airlift. I think that considerable more history exists than was recorded in this paper.

D. I. Coggins:* Dr. Breckenridge aptly singles out and emphasizes certain basic criteria pertaining to this subject for which I wish to thank him.

Mr. Douglas has done well to clear up a misunderstanding which may have existed in the directional characteristics of the incandescent approach lights. Experience has proven it necessary to radically reduce the intensity of these steady burning lights during night fog conditions to avoid glare and loss of dark adaptation.

Dr. Strange emphasizes the importance of continuous horizon information to which I certainly subscribe. It is reasonable to say that, within limits, the longer the transverse light bar the more effective the roll guidance. Economics dictates the point of diminishing returns.

Mr. Projector raises several interesting points which demonstrate the natural latitude which may exist in the interpretation and application of a particular theory to a given problem.

I should like to say immediately that no violation of the laws of the conservation of energy appears to be involved here. However, the Blondel-Rey theory is too frequently considered law for conditions which there is doubt that the authors themselves intended. An analysis of the conditions of these experiments stands to support the hundreds of favorable pilots' reports which are the result of approaches made under a complete range of visibility and conditions far more inclusive than the laboratory tests attempted. The initial Blondel-Rey studies, I believe, followed a procedure not only the reverse of the basic conditions facing a pilot, but lacking in several major respects the severity and complexity of low visibility flight. They were based upon "fade out" and regression from the light source rather than "locate" and "approach to" a light source. It further appears that these tests were performed in clear laboratory atmosphere, unconfused by random adjacent lights, unaffected by high background fog illumination, and unhampered by time-response limitations — all conditions at times confronting a pilot.

Mr. Projector supports the view that flash effectiveness is a function only of energy, regardless of the individual values of intensity and time-within limits. In daytime fogs with high background illumination it is clearly necessary for a light source to exceed this illumination level by a calculable amount to be seen at all. Thus it is quite doubtful that in fact all equal products of time and intensity will produce the same effectiveness under all conditions.

On the matter of efficiency, it is likely that condenser discharge would actually be superior to a simulated shutter-produced flash from a steady burning light source. Furthermore, to filter an incandescent light for color matching to condenser discharge would most certainly reduce the efficiency of the former still further.

I want to thank Mr. Projector for his extensive discussion of this most important subject.

To Mr. Butler, I am indebted for an interesting sidelight on the nature of scattered light.

Mr. Beggs has summarized nicely for us the part condenser discharge can and does play in the highly vital field of aviation lighting aids. Actual flight tests and laboratory studies appear to clearly support the superiority of condenser discharge in minimizing dazzle and preserving essentially full dark adaptation of the eye.

I would like to thank Mr. Keck for his comments. Low visibility landings utilize the combined information given by radio, radar, specialized visual light sources, configurations and color.

* Author.

Applications for Retired Membership

By action of the membership of I.E.S., the new retired membership classifications became effective in the fiscal year beginning last October. Privileges in these new grades, earned by long membership in the Society, include reduced annual dues ($5.00) with continued receipt of all Society mailings including Illuminating Engineering. Such members will be designated as Member, Retired; Associate Member, Retired.

Those who are interested and qualified (at least thirty years of membership and 65 years of age) should address a letter to the General Secretary at Society Headquarters, stating that they have retired from regular occupation in business or profession.

Views and Opinions

The Employee Takes a Dim View Of Lighting

To some of us engrossed in lighting it may come as a shock to realize that a large group of employees outside the industry, when given opportunity to name the main benefits of their jobs, placed lighting 42nd in a list of 58 benefits.

The source of this information is the contest* conducted by General Motors Corp. on "My Job and Why I Like It." The employees were unconfined in what they chose to write about in the 174,854 entries. Answers were carefully analyzed after the contest in order to collect material for the enlightenment and education of the supervisory and management groups, and to obtain a body of data for the analysis of employee attitudes.

Each entry was a personal document, a record of a person's thoughts, when minds were at liberty to write about subjects of importance to themselves.

This study is important to the lighting industry. General Motors Corp. is a highly successful operation. The offices and plants are lighted to standards not generally found in industry. Most of the employees responded, rather than a few articulate members. Analysis of the entries showed that the range of G.M. divisions' participation was from 28.5 per cent to 100 per cent. The entries were not from a few discriminating, literary persons, but from a true cross-section.

It is good news to the illuminating engineer to know that lighting ranked ahead of pension plans, plant location and transportation, washrooms, information services, paid holidays, parking facilities, locker rooms, rest periods, open house, and others. In contrast, however, lighting showed up poorly in comparison with 41 other themes which impressed the employee. Among them were supervision, associates, wages, pride in company, management, training, insurance, security, pride in product, paid vacation, recreation, hospitalization, parties and picnics, air and temperature and cafeterias.

It is evident that to try to sell a lighting job through the employees would be most difficult unless to a group familiar with the immediate and long-range benefits. It would appear that today employees would be influential in lighting only if it were extremely substandard. Without employee education, it is most unlikely that lighting would take preference over many of the 41 fringe benefits mentioned.

Percentage Distribution of 58 Themes in All Divisions

	Theme Name	All Divisions Mention (% of Total Entries)
1.	Supervision	47.9
2.	Associates	41.2
3.	Wages	40.9
4.	Work Type	33.7
5.	Pride in Company	32.2
6.	Management	31.3
7.	Training, Education, Experience	28.7
8.	Opportunity for Advancement	25.6
9.	Insurance	23.7
10.	Security	22.8
11.	Pride in Product	22.8
12.	Pride in Stability of Company	21.5
13.	Benefits from Wages	21.5
14.	Teamwork	21.4
15.	Pride in Important Job	20.2
16.	Safety	18.6
17.	Tools, Methods, Equipment	16.6
18.	Steady Work	16.3
19.	Fair Treatment	15.7
20.	Paid Vacation	15.1
21.	Non-Discrimination	14.3
22.	Recreation	14.0
23.	Medical Facilities	11.5
24.	Cleanliness	11.1
25.	Suggestion Plan	10.5
26.	Job Description	10.1
27.	Comparison — Other Companies	9.4
28.	Hospitalization Plan	8.9
29.	Company and America	8.7
30.	Working Hours	8.5
31.	Free Enterprise	8.0
32.	Savings Plan	7.9
33.	Comparison — Other Jobs	7.5
34.	Personal History	7.2
35.	Pride in Years of Service	7.1
36.	Parties and Picnics	6.6
37.	Suitable Placement	6.2
38.	Air and Temperature	6.0
39.	Cafeteria	5.9
40.	Employee Relations	5.8
41.	Personnel Policies	5.4
42.	**Lighting**	**5.4**
43.	Pension Plans	4.6
44.	Modern Plant	3.5
45.	Plant Location and Transportation	3.5
46.	Personnel Department	3.4
47.	Washrooms	3.2
48.	Information Services	3.2
49.	Success Theme	3.1
50.	Pride in Community Relations	2.6
51.	Paid Holidays	2.5
52.	Parking Facilities	2.4
53.	Leaves of Absence	1.8
54.	Pride in Building Good Product	1.8
55.	Seniority	1.3
56.	Locker Rooms	1.1
57.	Rest Periods	0.8
58.	Open House	0.3

T. D. WAKEFIELD
Executive Vice-President
The Wakefield Co.
Vermilion, Ohio

*Reference: My Job Contest — An Experiment in New Employee Relations Methods Part II. Management Listens to Its Employees — The Research Jog. By Chester E. Evans and Laverne N. Laseau, General Motors Corp. *Personnel Psychology*, Vol. II, No. 2, Summer, 1949.

LIGHTING NEWS

Council Meets in New York City— Summary of Action Taken

The Council of the I.E.S. met April 17 at the Park-Sheraton Hotel in New York City, President Marshall N. Waterman presiding.

The meeting began with an outline of the financial status of the Society, by General Secretary R. G. Slauer, and a communicated report from W. P. Lowell, Chairman of the Finance Committee.

Membership Statistics

Svend Bruun, Chairman of the General Board of Examiners, reported the election of 108 Associate Members and reinstatement of 13, and the election of 25 Student Members. Recommendation was made for the election/reinstatement of nine Members and the transfer of eight Associates to Member grade. Favorable action on the Board's report, with other membership changes, brought the membership figures to those shown in the following tabulation.

September 30, 1956		April 11, 1957
8480	Total Membership	8929*
37	Members Emeritus	39**
99	Fellows	97
2123	Members	2193
6036	Associate Members	6382
195	Student Members	218

*Includes 12 Members Retired, 7 Associate Members Retired.

**Includes 10 Fellows, 1 Honorary Member.

Sustaining Members

In the absence of Fred E. Guth, Chairman, Joe Browder presented recommendation for the election of five new Sustaining Members:

American Electric Supply Co.
5010 West Irving Park Road
Chicago 41, Ill.
Official Representative: Herbert Schwartz

Incandescent Supply Co.
647 Mission St.
San Francisco, Calif.
Official Representative: J. J. Newland

McWilliams Electric Co., Inc.
1820 North Rockwell St.
Chicago 47, Ill.
Official Representative: P. G. Schannon

Middletown Electrical Supply, Inc.
92 Center St.
Middletown, Conn.
Official Representative: Philip Busker

S. F. Lighting & Supply Co.
1147 Howard St.
San Francisco, Calif.
Official Representative: Russell Virgil

New Chapter and Transfers to Sections

Canadian Regional Vice-President Joe Thomas announced that the St. Maurice Valley group, at Trois Rivieres, Que., has met the Constitutional requirements as an I.E.S. Chapter, noting that a previous Council meeting had approved its Charter when these requirements were met. The St. Maurice Valley Chapter is the Society's 76th.

Three other Chapters were elevated to Section status on the recommendations of their respective Regional Vice-Presidents. These are: Miami Valley, Ottawa, and San Diego.

Action was also taken approving the request of the Southwestern Section for a change in name to North Texas Section.

Other General Committee Reports

The Procedures and Policies Committee submitted a statement on I.E.S. policy with respect to awards and trophies. Following discussion, the statement was referred back to the Committee for further clarification.

The Committee on Public Relations and Information, James Chambers, Chairman, presented a proposed public relations program, with a request for further funds to carry it out. A vote of the Council approved, subject to favorable recommendation by the Finance Committee, increased funds to support this program.

George J. Taylor, Chairman of the Regional Activities Committee, reported on a lively seminar on Effective Operation of Sections and Chapters, which the Committee held April 16. A report was also made, by Nelson Warner, on the analysis for Planned Chapter Development. The analysis would seem to show that in Canada there are only two large population centers without I.E.S. Sections or Chapters, and in the United States, 105 metropolitan trading areas are without I.E.S. centers. Recommendations for improving this situation were discussed.

Technical Reports

Activities of the I.E.S. technical committees were outlined by C. L. Crouch, Technical Director and three committee reports submitted for letter ballot. These are:

Testing Procedures Committee Report —"I.E.S. Guide for Photometric Measurements of Fluorescent Lamps."

Testing Procedures Committee — "I.E.S. Guide for Photometric Testing of Outdoor Fluorescent Luminaires."

Daylighting Committee — "Proposed Guide for Measuring and Reporting Daylight Illumination."

The General Secretary announced the favorable letter ballot on two committee reports:

Testing Procedures Committee — "I.E.S. Guide for Photometric Testing of Searchlights."

Industrial Lighting Committee — "Lighting of Indoor Locations of Central Station Properties."

Regional Conferences

Reports on the conferences held in the Pacific Northwest Region (Victoria, B. C.), the South Pacific Coast Region (Los Angeles, Calif.) and the Inter-Mountain Region (Albuquerque, N. M.) will be carried in the June issue of I.E.

Here and There With I.E.S. Members

LADIES NIGHT meeting of the Eastern Pennsylvania Section (right), on January 15 in Reading, Pa., featured Willard Brown as guest speaker. Left to right are: Mr. Brown; Frank Heins, meeting Chairman; Mrs. C. A. Oerkvitz, First Lady of Eastern Pennsylvania; R. J. Pretzman, Secretary-Treasurer; Fred Gochenauer and Paul Kinsey, Past-Chairmen.

FINALISTS in the Southern California Section contest for My Most Interesting Lighting Job, with the contest chairman. Left to right are: Harold Strahn, first place; Phil Martin, second; Jon Shirley, third; and Chairman Robert Ford.

COLOR and Light was the topic of guest speaker R. G. Slauer, I.E.S. General Secretary, at the March 19 meeting of the Western New York Section. In the photo are: Leo P. Gauthier, Mr. Slauer and Section Chairman Byron F. Lyth, Jr.

SOME of the more than 100 people who attended the March meeting of the Atlanta Residence Lighting Forum. Miss Ruth Patterson from Dallas was guest speaker, with the topic "Big Things Happen in Texas."

Outdoor Lighting — Topic for Full-Day Denver Meeting

New Developments in Commercial and Industrial Outdoor Lighting was the general topic of joint meeting, sponsored by the Rocky Mountain Section of I.E.S. and the Rocky Mountain Electric League, April 24 at the Hotel Shirley-Savoy, Denver.

I.E.S. President Marshall N. Waterman was featured speaker at the dinner climaxing the day's activities, during which eight speakers, from the East Coast to the West Coast, covered different aspects of the topic. Program and speakers were:

Morning

Movie on Playground Lighting.
Street Lighting — Stan Starr, Revere Electric Co., Chicago, Ill.
Trends in Floodlighting — Robert E. Faucett, General Electric Co., Outdoor Lighting Division, Hendersonville, N. C.
Outdoor Lighting Glassware — A. R. Jaeger, Corning Glass Works, Corning, N. Y.
Luncheon: Some Research Projects Needed — But Good — William A. Cyr, Editor, *Electrical West*. San Francisco, Calif.

Afternoon

Plastics in Lighting — H. A. Williams, Rohm & Haas, Philadelphia Pa.
The Present and Future of the Plastic Sign — James Howenstein, Neon Products, Inc., Lima, Ohio.
Effect of Low Temperature Ambient on Lighting System — Eugene Beggs, Westinghouse Lamp Division, Bloomfield, N. J.
Outdoor Applications of the Ballastless Mercury Vapor Lamp — Herbert A. Anderson, Duro-Test Corp., North Bergen, N. J.
Dinner: Speaker, I.E.S. President, Marshall N. Waterman, Westinghouse Electric Corp., Bloomfield, N. J.

In addition to members of the Rocky Mountain Section and Southern Colorado Chapter of I.E.S. and the Electric League, invitations were sent to other electrical contractors, sign companies, architects, oil companies, state and city officers, recreation departments and the public utilities.

Panhandle Chapter March Meeting— A Drama in Two Acts

Newspaper headlines all over the country told of the record blizzard which, beginning the night of March 22, covered the area from Wyoming to the Oklahoma and Texas Panhandles. A report from Amarillo, Texas, gives an inside story on how I.E.S. members coped with the blizzard to hold their regularly scheduled meeting. Announced as speaker was Charles K. Champlin, Illuminating Engineer of Edwin F. Guth Co., St. Louis.

By mid-Monday, Amarillo was beginning to dig out. That evening the meeting began on time. Gene Woodall, Guth representative from Dallas, who got in

(*Continued on page* 12A)

SCHEDULED EVENTS

May 20-24, 1957 — National Fire Protection Association, Annual Meeting, Statler Hotel, Los Angeles, Calif.

May 23-24, 1957 — East Central Regional Conference, Illuminating Engineering Society, William Penn Hotel, Pittsburgh, Pa.

May 26-29, 1957 — National Association of Electrical Distributors, Sheraton-Park and Shoreham Hotels, Washington, D. C.

June 4-6, 1957 — Chicago Electrical Industry Show, Conrad Hilton Hotel, Chicago, Ill.

June 12, 1957 — I.E.S. Council Meeting, New York, N. Y.

June 13-14, 1957 — Northeastern Regional Conference, Illuminating Engineering Society, Hotel Statler, New York, N. Y.

June 14, 1957 — Society of Plastics Engineers, Regional Technical Conference, M.I.T., Cambridge, Mass.

June 24-27, 1957 — American Society of Heating and Air-Conditioning Engineers, Murray Bay, Quebec, Que.

June 24-28, 1957 — American Institute of Electrical Engineers, Summer General Meeting, Montreal, Que.

August 28-30, 1957 — American Institute of Electrical Engineers, Pacific General Meeting, Yakima, Wash.

September 9-13, 1957 — Illuminating Engineering Society, National Technical Conference, Biltmore Hotel, Atlanta, Ga.

September 24-26, 1957 — Institute of Traffic Engineers, Statler Hotel, Detroit, Mich.

October 4-9, 1957 — Society of Motion Picture and Television Engineers, Hotel Sheraton, Philadelphia, Pa.

October 5-8, 1957 — International Association of Electrical Leagues, Sinton Hotel, Cincinnati, Ohio.

October 7-9, 1957 — National Electronics Conference, Inc., Hotel Sherman, Chicago, Ill.

October 7-11, 1957 — American Institute of Electrical Engineers, Fall General Meeting, Chicago, Ill.

October 9-11, 1957 — Canadian Electrical Manufacturers Associaiton, Sheraton-Brock Hotel, Niagara Falls, Ont.

October 21-25, 1957 — National Safety Council, 45th National Safety Congress & Exposition, Chicago, Ill.

October 26-31, 1957 — National Association of Electrical Distributors, (Semiannual Meeting), Edgewater Beach Hotel, Chicago, Ill.

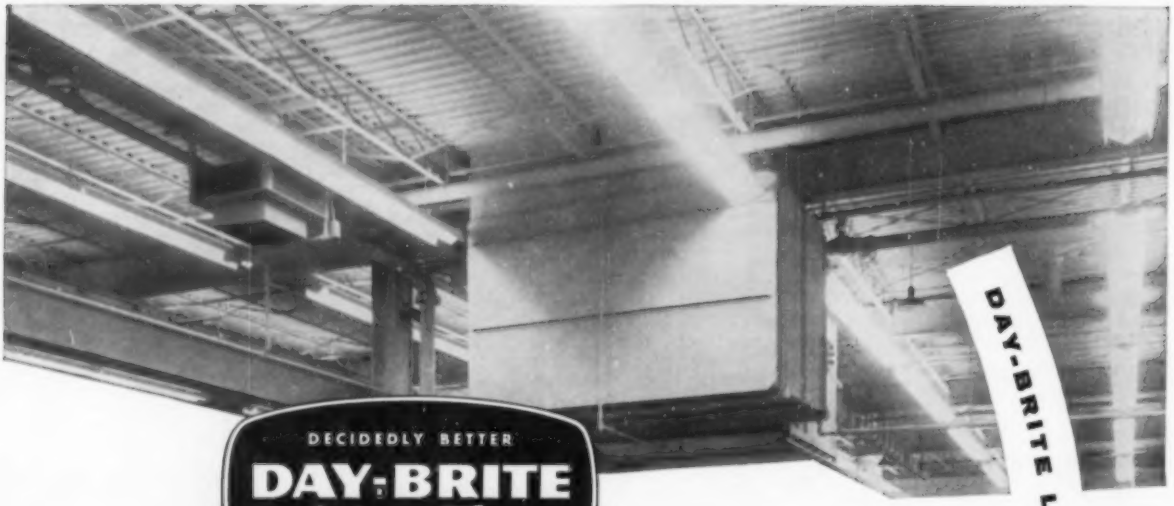
October 27-30, 1957 — National Association of Electrical Distributors (Board of Governors), Skytop Lodge, Skytop, Pa.

Week of November 10, 1957 — National Electrical Contractors Association, Cincinnati, Ohio.

November 11-15, 1957 — National Electrical Manufacturers Association, Traymore Hotel, Atlantic City, N. J.

November 18-21, 1957 — 10th Exposition of the Air-Conditioning and Refrigeration Industry, Navy Pier, Chicago, Ill.

PRINCIPALS in the two-part meeting of the Panhandle Chapter, I.E.S., March 25-26. Left to right: Tom Lynn, Chapter Chairman; Gene Woodall, Guth representative from Dallas; Charles K. Champlin, who fought a blizzard to keep his engagement. Not shown, I.E.S. members who attended two sessions to hear the talk on "Luminous Ceilings."



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DAY-BRITE LIGHTING MAKES THE BIG DIFFERENCE HERE

Lower costs with new high-output CFI

Equipped with new high-output, rapid-start lamps, the new Day-Brite CFI (Comfort For Industry) fixtures provide a high level of over-all illumination at lower over-all cost.

The new CFI fixtures are designed with slotted openings in the reflector tops which direct a portion of the light to the ceiling and permit natural updraft ventilation. Maintenance is reduced because reflectors and lamps stay cleaner longer—resulting in extra light at no extra cost. Also, eyestrain and fatigue are minimized because harsh ceiling contrasts are washed out.

For the newest idea in industrial lighting, consult your Day-Brite representative. He's listed in the Yellow Pages. Send for new CFI literature. *Day-Brite Lighting, Inc., 5432 Bulwer Ave., St. Louis 7, Mo.*

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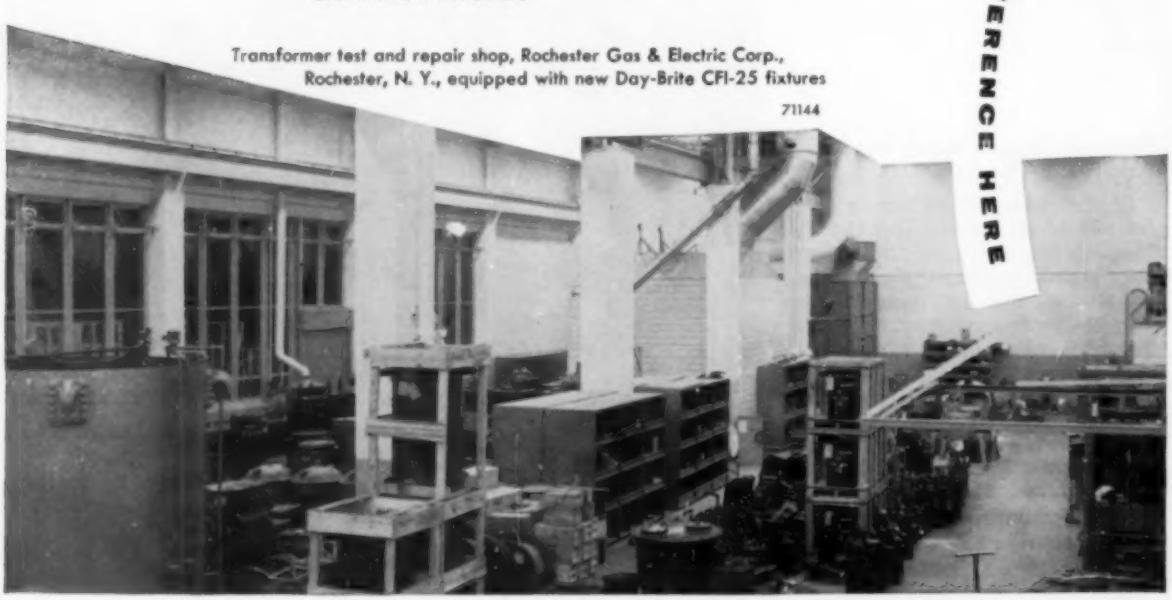
OF COMMERCIAL AND INDUSTRIAL
LIGHTING FIXTURES



Transformer test and repair shop, Rochester Gas & Electric Corp., Rochester, N. Y., equipped with new Day-Brite CFI-25 fixtures

71144

Some of the many television, studio and stage lighting lenses produced by Corning.

Light paints magic pictures on TV screens in homes throughout the land. But before the wizardry of electronics takes over, *controlled* light in the studio gives vision to the camera's eye.

And Corning lenses give lighting fixture manufacturers the precision, control, and economy they require.

Lenses for studio lights are just one of many purposefully *engineered* glass products for making light do man's bidding.

You are invited to take advantage of Corning research and facilities in getting the special lenses to handle your light control problems. Your inquiry will be promptly answered.

CORNING GLASS WORKS
CORNING, NEW YORK

Corning means research in Glass

(*Continued from page 9A*)

before the storm, attended. He was trying to find Mr. Champlin, but Mr. Champlin . . . ?

Mr. Champlin had started from St. Louis by plane, was grounded in Kansas City, from where he got a Santa Fe train, due in Amarillo on Monday morning. He reckoned without the storm. The meeting kept going as long as possible, with no guest speaker.

The following day, Panhandle Chapter members completed their regularly scheduled meeting. Mr. Champlin spoke on "Luminous Ceilings" to a luncheon group nearly as numerous as that which had gathered the evening before.

A determined lot, these I.E.S. members.

ORGANIZATIONAL meeting of the Dallas Residence Lighting Forum on March 29.

Residential Lighting Forum Organized in Dallas

A highly successful organization meeting was held March 29, with an attendance of 46 to start the Residence Lighting Forum of Dallas, Texas, on its way. The dinner meeting was sponsored by the Dallas Power and Light Co.

John Deck, Chairman of the Southwestern Section, I.E.S. opened the meeting following dinner and introduced Clarence Cockrell, Temporary Chairman of the Forum. Mr. Cockrell outlined the advantages, purposes and functions of such a forum. Membership in the new group is: 11 decorators, 11 utility personnel, 9 electrical wholesalers, 8 manufacturers' representatives and 4 electrical contractors.

Following the dinner meeting, those attending were invited to inspect the home of Miss Ruth Patterson, which was the winning entry in the residential section of the Section's recent contest for My Most Interesting Lighting Job.

VISIT to the home of Miss Ruth Patterson followed the business session of the Dallas Residence Lighting Forum. Left to right are: Miss Ann Hardin, Oscar Springfield, Mrs. Cecille Hargrove, Miss Ruth Patterson, Clarence Cockrell, Mrs. Lucile Payne and Frank Payne. Miss Patterson's home won first prize in the residential part of the Southwestern Section's contest for My Most Interesting Lighting Job.

Twin Cities Lighting Fair — A Conference and Exposition

The Twin City Section of I.E.S. and the North Central Electrical League joined with the Northern States Power Co. on March 26 and 27 in sponsoring a 1957 Twin Cities Lighting Fair, at the Calhoun Beach Hotel in Minneapolis.

The Fair consisted of educational meetings, featuring nationally-known speakers, coordinated with a lighting equipment exposition. Architects and engineers attended the March 26 session, and electrical contractors and distributors on March 27. Each day's program began with a buffet lunch, followed by afternoon discussions on lighting in hospitals, churches, offices, schools, stores, filling stations, factories and parking lots, concluding with a dinner meeting.

Main speaker at the dinner March 26 was C. L. Crouch, I.E.S. Technical Director. This was scheduled as the regular monthly meeting of the Twin City Section.

(*Continued on page 15A*)

Address Changes should be reported to I.E.S. Headquarters by the first of any month, to insure the uninterrupted mailing of I.E. and other Society communications.

IN SUN-TAN BROWN for accentuating yellow and brown tones . . . bringing out elusive colors . . . to create a charming air of intimacy and surround a room with warm friendliness.

IN SEA-MIST GREEN for specifically emphasizing cool color schemes . . . highlighting greens and blues . . . and adding new dimension, airy spaciousness to small, confined areas.

New Westinghouse carousel luminaires

A new idea in color lighting to accentuate decor in offices, stores and schools

Color comes alive with new Westinghouse Carousel luminaires — snaps to attention for you in perking up office morale, sparking merchandise with extra sales excitement and appeal. You get the same animation in classrooms.

Colored metal side panels and all-metal louvers in the new Carousel luminaires diffuse a soft, smooth wash of light which emphasizes specific colors without repelling others.

With new Carousel lighting, colors literally sing in harmony to create exactly the working and seeing atmosphere you desire and need.

Carousel luminaires are comfortable to see by — equally easy to look at. They take the edge off annoying brightness — eliminate glare. And their colorful, smartly styled appearance adds a subtle touch of beauty to any decorating scheme.

Call your local Westinghouse lighting representative for *all* the colorful details on new Carousel lighting. Or, write Westinghouse Electric Corporation, Lighting Division, Edgewater Park, Cleveland, Ohio. J-04407-A

YOU CAN BE SURE... IF IT'S

Westinghouse®

Early street lighting unit at Whitehall and Alabama Streets, Atlanta, still burning as a memorial to the Old Guard Battalion of the Confederacy. In the background, a 20,000-lumen mercury vapor luminaire, typical of the street lights that make Atlanta one of the best lighted cities in the U.S.

ATLANTA

HAS A
CANDLE IN
THE WINDOW
For

I·E·S

THIS YEAR

IN ADDITION TO . . .

a full presentation of the latest developments in the art and science of illumination.

WE ARE PLANNING . . .

- **A Plantation Party**
- **An Old Fashioned Barbecue**
- **Historical Tours**
- **Ladies' Events**
- **Golf**

Y'all Come!

1957 National Technical Conference

Illuminating Engineering Society

Atlanta Biltmore Hotel September 9 - 13

(Continued from page 12A)

Advanced Lighting Course Offered in Tampa, Florida

Beamed especially at electrical contractors and their employees, an advanced lighting course was recently sponsored by the Florida Section, I.E.S. and the Lighting Department of Tampa Electric Co. Attendance averaged 85 at the seven meetings and 72 enrollees attended the five classes required to "graduate" and receive "diplomas."

Topics and speakers at the seven sessions were:

1. Fundamentals and Calculations — James A. Banton.
2. Light Sources — M. L. Harkey.
3. Lighting Design — James A. Banton.
4. Store Lighting — E. A. Bartlett.
5. Office Lighting — John J. Neidhart.
6. Industrial Lighting — E. B. Bradford.
7. School Lighting — William Foulks.

It was the unanimous opinion of the group that a similar lighting course be held next year.

ATTENDANCE averaged 85 at each of the seven sessions of the Florida Section advanced lighting course. Here W. V. C. Foulks speaks on "Candles and Comfort" at the final meeting.

Street Tree and Utility Conference Summarizes Recent Meeting

All reports of the Second Street Tree and Utility Conference, held March 7 and 8 in Cleveland, Ohio, add up to the conclusion that it was a gratifying success. Total registration was 218 from 23 states and two provinces of Canada. At its conclusion, the registrants voted overwhelmingly to hold another such conference in two or three years.

Two changes from the tentative program (as listed on page 7A, February I.E.) were made, with S. A. Kaufman of Cleveland, Ohio, American Institute of Planners, presenting the paper "The City Planner Looks at Long-Range Street Design," and the Dinner Address at the March 7 session being presented by Louis Seltzer, Editor, *The Cleveland Press*. Mr. Seltzer's talk was entitled "This Street Program from an Editor's Viewpoint" Kirk M. Reid, I.E.S. sponsor of the conference, was chairman at this meeting.

Printed proceedings covering all papers and all discussions are expected to be available in three or four months. Single copies may be ordered now at a price of $3. It is expected that after printing costs are known, a lower rate will be applicable to copies purchased in bulk. The Edison Electric Institute is handling the printing of the proceedings, and orders should be sent to E.E.I.

(Continued on page 16A)

BUSINESS session at the Second Street Tree and Utility Conference.

(*Continued from page* 15A)

Southwestern Section Sponsors Applied Lighting Course

An eight-session course covering 18 different lighting subjects has been sponsored by the Southwestern Section of I.E.S. The classes were held Monday evenings from 7 to 9 p.m. at the Northeast Service Center of the Dallas Power & Light Co., in Dallas. Larry Cole was course coordinator and H. R. Heitzman, Chairman of the Section's Education Committee.

The enrollment of 83 included 30 electrical contractors, 22 distributors, 15 I.E.S. members, 13 utility personnel and 3 consulting engineers.

The 18 topics covered and the speakers were:

March 4

1. How We See — Ruth Patterson.
2. Light and Vision — Ruth Patterson.
3. Illumination Terminology — Ralph Heitzman.

March 11

4 and 5. Quality Requirements — John Deck.
6. Color and Lighting — John Felton.

March 18

8. Incandescent Lamps — V. J. Graham.
8. Mercury and Discharge Lamps — V. J. Graham.
9. Fluorescent Lamps — Tom Ewbank.

March 25

10. Principles of Light Control — Bill Campbell.
11. Systems of Light Control — Harold Samuels.

April 1

12. Calculation of Illumination — John Felton and Billy Cook.

April 8

13. Office Lighting — W. E. Folsom.
14. School Lighting — W. E. Folsom.

QUIZ time at the Southwestern Section's applied lighting course followed the instruction and slide film period.

April 15

15. Store Lighting — John Deck.
16. Industrial Lighting — Tom Moore.

April 22

17. Floodlighting — John Metzinthin.
18. Cost and Maintenance — V. J. Graham. Review — Ralph Heitzman.

Graduation was held May 6 at the regular monthly meeting of the Section.

Second Design Engineering Show May 20-23, New York City

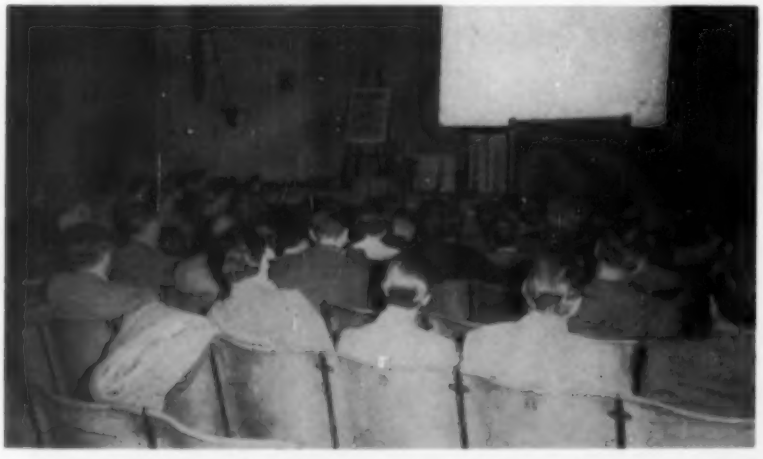
Component parts, materials, fasteners, finishes and coatings, shapes and forms, and accessories to product development are on exhibit at the second Design Engineering Show, May 20-23 at the New York Coliseum, New York City.

Concurrently with the exposition, the machine design division of the American Society of Mechanical Engineers is sponsoring a three-day conference on design engineering problems — the electrical, mechanical and materials aspects.

British Columbia Section Holds Fundamentals Course

A complete course on the fundamentals of lighting, in eleven weekly lectures illustrated by films and demonstration equipment, attracted an enrollment of 140 in the British Columbia area.

The course, sponsored by the British Columbia Section of I.E.S., covered the theory of light, partnership of light and sight, industrial, office, school, store and residential lighting, as well as fundamentals on home wiring. Speakers were leading authorities in the lighting industry. Chairman of the course committee was H. G. Foster, Illumination Specialist, Northern Electric Co., Ltd., Vancouver.



FUNDAMENTALS of lighting attracted an enrollment of 140 to the British Columbia Section's 11-week course.

Increase Reported in Engineering Student Enrollment

More students are preparing for engineering careers this year than at any time since 1948. Figures compiled by the United States Office of Education (U. S. Dept. of Health, Education and Welfare) and the American Society for Engineering Education show a total of nearly 243,000 studying in accredited engineering colleges last fall.

This total is almost equal to the all-time high of 1947, and the trend is reported as still upward. Enrollment of senior students is up 20 per cent over 1955. Electrical engineering has taken

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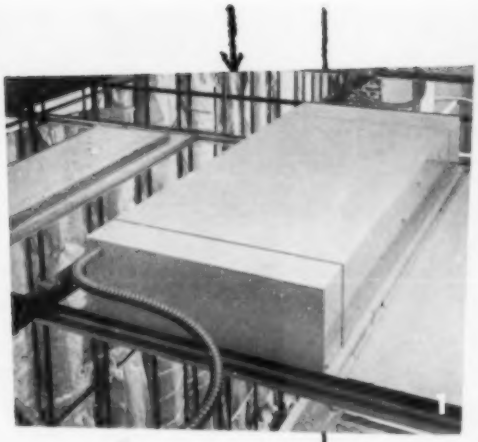
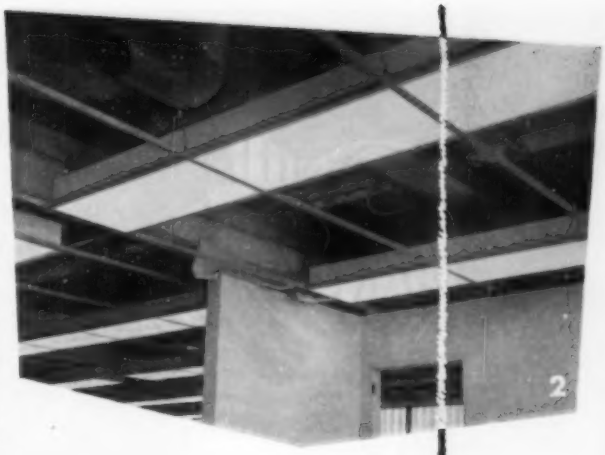
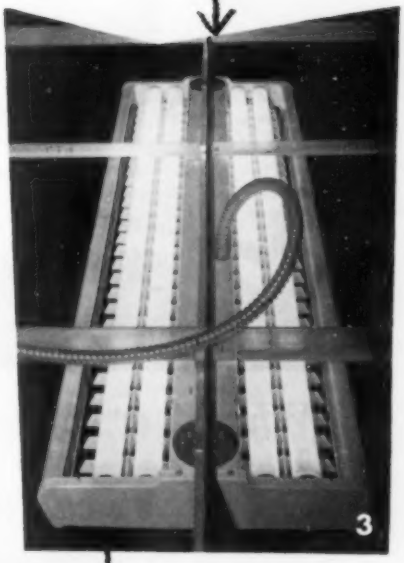




MORE SUNBEAM LIGHTING GOES UP AS CEILING HEIGHTS COME DOWN

In keeping with the modern trend toward lower and more functional ceiling arrangements, Sunbeam Lighting Visionaires® prove their adaptability and flexibility daily. New ceiling construction methods are kept under constant study by our engineers so that maximum versatility and simplicity of installation are designed into every fixture. Our recessed, "large area" 3600 series, for instance (photos 1 and 2), are as easily installed or relocated within suspended ceiling systems as the acoustical panels themselves. Other units, such as the standard 5600 series troffers, are adaptable to a wide range of installation requirements including suspended, "snap-in" T-bar mounting (photo 4).

Our newly developed CSM7 hanger for "surface mounting" of luminaires directly onto suspended ceiling runners eliminates the need for separate and costly hanging systems (photo 3). Every effort is made to construct Sunbeam Visionaires® so that they may be installed and maintained with minimum use of tools.



Remember, for the ultimate in shallow, surface-mounted fixtures, it's the SHALLORAMA!

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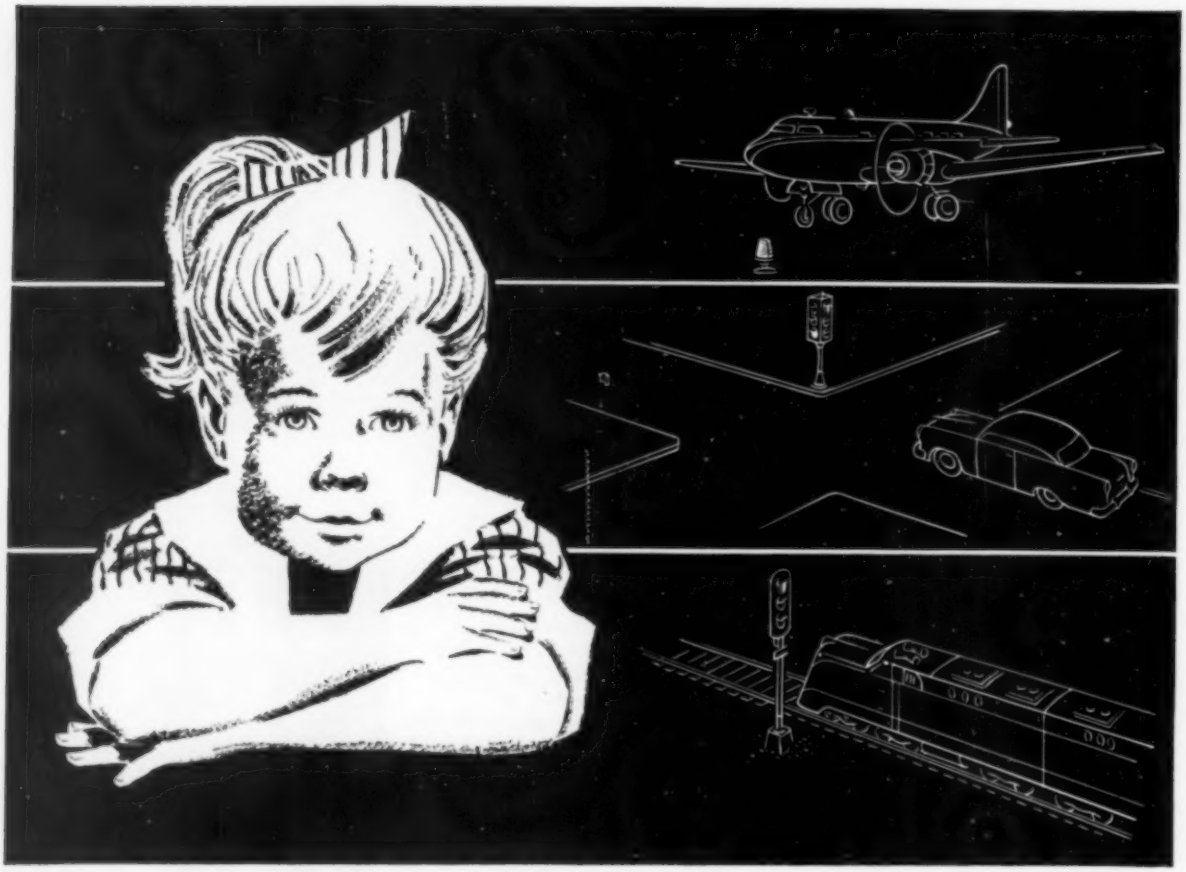

Where her safety is involved . . .

you can depend on **Kopp** *engineered glass*

Why? Because Kopp glass is precisely designed for its specific job. Whether your requirements call for color transmission, light distribution, beam control, dimensional accuracy or any other individual characteristic—Kopp engineers design industrial glass products to meet those exact needs.

Furthermore, a Kopp-engineered product is manufactured of the finest, carefully-formulated ingredients. Every step in the production process is individually and rigidly controlled. Each product is thoroughly inspected and tested to assure highest quality and uniform dependability. That's why users of Kopp glass always receive top-quality performance—mighty important where human safety is involved.

Only a few of more than 1000 highly-specialized items made from over 100 varieties of glass by Kopp are shown below. Call us today for assistance in solving any industrial glass application problem which you may have.

KOPP GLASS

KOPP GLASS, Inc.

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(*Continued from page 16A*)

over first place as today's most popular field, with mechanical, civil, chemical and aeronautical engineering following in that order.

A full report on the 1956-1957 enrollment has been published by the ASEE in its March 1957 issue of the *Journal of Engineering Education*.

British "Light and Lighting" Features Cinema Lighting

A special feature on cinema lighting is included in the March 1957 issue of *Light and Lighting*, the publication of the British I.E.S. Articles on the subject cover Decorative Lighting of Auditoria and Foyers, Recently Completed British Cinemas, "Maintained" and Safety Lighting, External Lighting, Technical Aspects of Cinema Lighting, Examples from Abroad.

Copies of this issue may be obtained from the magazine at 32, Victoria St., London, S.W. 1, price 3/ including postage.

CLI Offers Annual Spring Courses

The Chicago Lighting Institute, the Chicago Section of I.E.S. and the Illinois Institute of Technology are again this year co-sponsoring the annual Spring courses in Lighting Fundamentals and Wiring Design. Raymond Wozniak is instructor for both the lecture and laboratory sessions of the fundamentals course, which runs from April 1 through June 17. Frank R. McShane is instructor for the wiring course, April 9 through June 11.

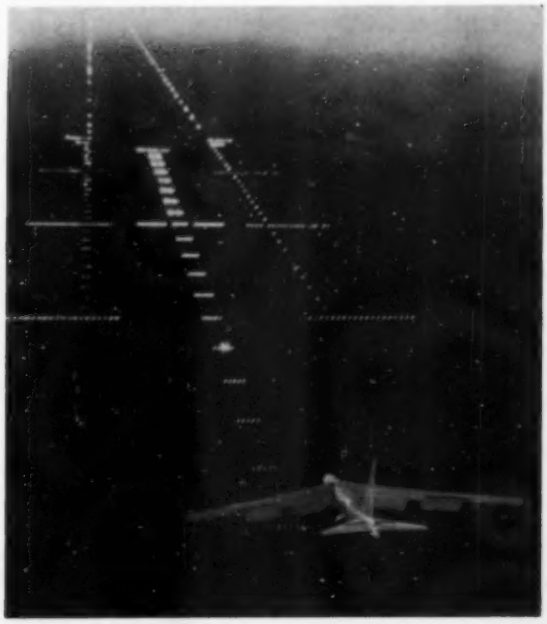
1957 Regional Conferences, I.E.S.

Region	Place	Date
Canadian	Sheraton Brock Hotel Niagara Falls, Ontario	May 16-17
East Central	William Penn Hotel Pittsburgh, Pennsylvania	May 23-24
Northeastern	Statler Hotel New York, New York	June 13-14

New Approach Lighting System Commissioned by U. S. Air Force

The United States Air Force has commissioned, at March Air Force Base, Calif., a new approach-lighting system whose lightning-like flashes aid all-weather operation of huge jet bombers at this major base of the Strategic Air Command, according to information received from Headquarters, 15th Air Force.

Major General Archie J. Old, Jr., Commander of SAC's 15th Air Force, has said that the lighting installation, developed by Sylvania Electric Products Inc., is designed especially for the operation of such aircraft as the eight-jet B-52 Stratofortress and other high-performance aircraft with increased landing speeds. Brilliant, fog-piercing lights form the heart of the system — known as EFAS (see this issue I.E., page 289). These high intensity center-line lights provide identification for incoming planes by flashing swiftly in sequence toward the runway from nearly 3000 feet out.



LANDING gear and flaps down, an eight-jet U. S. Air Force B-52 Stratofortress descends over the new approach lighting system at March Air Force Base, Riverside, Calif.

International Competition for Solar-Heated Residence Design

An international architectural competition to obtain designs for a solar-heated residence, particularly adapted to "Living With the Sun" in the Southwestern United States, has been announced by Jan Oostermeyer, president of the Association for Applied Solar Energy of Phoenix, Ariz. Mr. Oostermeyer has said that $2500 and a contract to supply architectural services for the actual building of the winning design are offered as first prize. Awards of $1500, $750 and $500 will be made to the contestants whose designs are found to be next in order of excellence.

The competition, open to practicing architects, designers and students throughout the world, will close on August 15, 1957. Professional advisor for the contest is James M. Hunter, Fellow A.I.A., of 1126 Spruce St., Boulder, Colo. Prospective contestants may obtain from Mr. Hunter, at any time up to June 1, 1957, the detailed program for the competition. This program contains the requirements which contestants must meet, as well as the specifications for the residence and the Phoenix area climate data.

The first prize-winning design will be incorporated into a residence to be built at Sundown Ranch in the Paradise Valley area northeast of Phoenix. The residence is to be designed for a typical Arizona

(*Continued on page 20A*)

(*Continued from page* 19A)

family, but the architect will be given a free hand in his interpretation of the most effective way to meet the family's needs. He must also provide the solar collection area necessary to supply the heat requirements of the residence. A swimming pool and its heating equipment will be included as an integral part of the design.

Jurors, who will meet September 14 and 15 at Grand Canyon, to select the winning designs will be Pietro Belluschi, Dean of Architecture and Planning, Massachusetts Institute of Technology; Carlos Contreras, architect, Mexico City; Thomas Creighton, editor, *Progressive Architecture;* James W. Elmore, Associate Professor of Architecture, Arizona State College; and Nathaniel Owings, partner, Skidmore, Owings and Merrill.

ABOUT PEOPLE

Gordon Thompson, chief engineer of Electrical Testing Laboratories, Inc., has been elected vice-president and **Robert N. Lankering** has been appointed staff assistant to president Hoffman S. Beagle. Mr. Thompson, one of ETL's original incorporators and directors has been associated with the firm since 1909, except for the years 1920 to 1927, when he served as Professor of electrical engineering at Nanyang University, Shanghai. Mr. Lankering comes to ETL from the Ford Motor Co., where he was a project engineer.

The election of **C. E. Wolfe** to the post of vice-president, sales, has been announced by Curtis Lighting, Inc. Mr. Wolfe was formerly general sales manager of Liquid Carbonic Corp.'s carbon dioxide division. Curtis Lighting also announces the appointment of **Russell E. Owen** as advertising and sales promotion manager. Mr. Owen was formerly merchandising manager for the illuminating and rolling mill divisions of Miller Co.

Establishment of six new service districts, four new components, and the appointment of 10 new managers in General Electric Lamp Division's Warehousing and Field Service Section have been announced by the managers of the Service Regions involved. The six new districts and their respective managers are: Tampa (Fla.) Service District in the Southern Service Region, with **Dale H. Sacia** as manager; Rock Island (Ill.) Service District in the Central Service Region, with **Vaino J. Saari** as manager; New Orleans (La.) Service District in the Southern Service Region, with **Philip J. Pendergast** as manager; Houston (Tex.) Service District in the Midwestern Service Region, with **James H. Strain** as manager; Charlotte (N. C.) Service District in the Southern Service Region, with **Thomas P. Holden** as manager; Baltimore (Md.) Service District in the Southern Service Region, with **Allen B. Minter** as manager. The four new components and their managers are: Procedures and Data Processing, in the Southern Service Region with **William C. Oddy** as manager. Mr. Oddy will be located in Atlanta, Ga. Customer Accounting, in the Eastern Service Region, with **Edward C. Longstreet** as manager, in Newark, N. J.; Procedures and Data Processing in the Central Service Region, with **John E. Boyd** as manager, located in Chicago; Customer Accounting in the Central Service Region, with **Arthur E. Shaw** as manager, with headquarters also in Chicago.

Officers of the recently-formed Sylvania-Corning Nuclear Corp have been announced by the company's Board of Directors. They are: **W. Benton Harrison,** Chairman of the Board; **Dr. Lee L. Davenport,** President and Treasurer; **Walter E. Kingston,** Executive Vice-President; **Garth W. Edwards,** Controller; and **Howard M. Cohen,** Secretary.

G. A. Hochenauer has been appointed Sales Engineer for the Smoot-Holman Co., Inglewood, Calif., and will be in charge of servicing accounts in the Southern California area. Mr. Hochenauer has been an active member of I.E.S. for many years, and is currently Chairman of the Southern California Section.

Charles C. Warne, Jr., has been named vice-president in charge of sales of Hubbard and Co.'s electrical materials and aluminum products. Having joined the company in 1936, Mr. Warne has been vice-president and general manager of the aluminum products sales and manufacturing operations since 1950.

Sylvania Electric Products Inc. has announced the appointment of **Robert E. Lewis** as Assistant to the President, on special assignments. A Vice-President of the company, Mr. Lewis will also continue as President of Sylvania's Argus Cameras Division.

The General Electric Co. Apparatus Sales Division has formed a new South Atlantic Sales District, effective May 1, to service North Carolina, South Carolina, Tennessee and Virginia. Headquarters for the new district are in Charlotte, N. C. **J. Frank McElwee, Jr.,** formerly the Department's Tennessee Area Manager, is Manager of the new district. **R. H. Jackson,** with headquarters in Atlanta, is Manager of the Southeastern District, serving Georgia, Alabama, Florida, Mississippi and part of Louisiana.

Philip P. Wienick has been named National Sales Manager of Modern Light & Equipment Co., Chicago, Ill.

Appointment of the L. V. Walker Co. as sales representative for the San Francisco territory for Pittsburgh Reflector Co. has been announced. Heading the new organization is **Leonard V. Walker.**

Swivelier Co., Inc. has named **Ira Newman** as their representative in the New York City area. Mr. Newman has been with the company since 1949 as lighting specialist and sales engineer. He is the Treasurer of the New York Section of I.E.S.

Dr. L. J. Buttolph, I.E.S. Fellow, has been appointed executive secretary of the National Noise Abatement Council. Dr. Buttolph, a resident of Cliffside Park, N. J., recently retired from the General Electric Co.

The Unistrut Products Co., Chicago, has appointed **Clem Kopf** as manager of its distributor organization, Unistrut Philadelphia, 530 N. 21st St. Mr. Kopf was formerly a branch manager for Westinghouse Electric Supply Co.

(*Continued on page* 23A)

I.E.S. National Technical Conferences

1957 — September 913 — Biltmore Hotel, Atlanta, Georgia
1958 — August 17-22 — Royal York Hotel, Toronto, Ontario
1959 — September 7-11 — Hotels Fairmont and Mark Hopkins, San Francisco, California
1960 — September 11-16 — Penn Sheraton Hotel, Pittsburgh, Pennsylvania
1961 — September 24-29 — Chase Park Plaza Hotel, St. Louis, Missouri

see the man from Smoot-Holman first!...

...for the best in school, commercial and industrial lighting

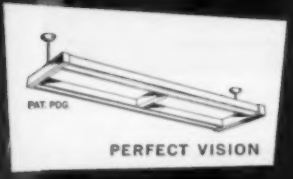
No matter how difficult the illumination problem — the Smoot-Holman lighting expert is the **man to see!** Here is trained "know-how" backed by Smoot-Holman's modern plant facilities and quality lighting equipment.

Call your local Smoot-Holman office or write direct. Ask to **see the man** from Smoot-Holman.

SKYLIKE

MASTER FLOOD

RECESSED TROFFER


PAT. PDG.
PERFECT VISION

RLM DOME

EDUCATOR

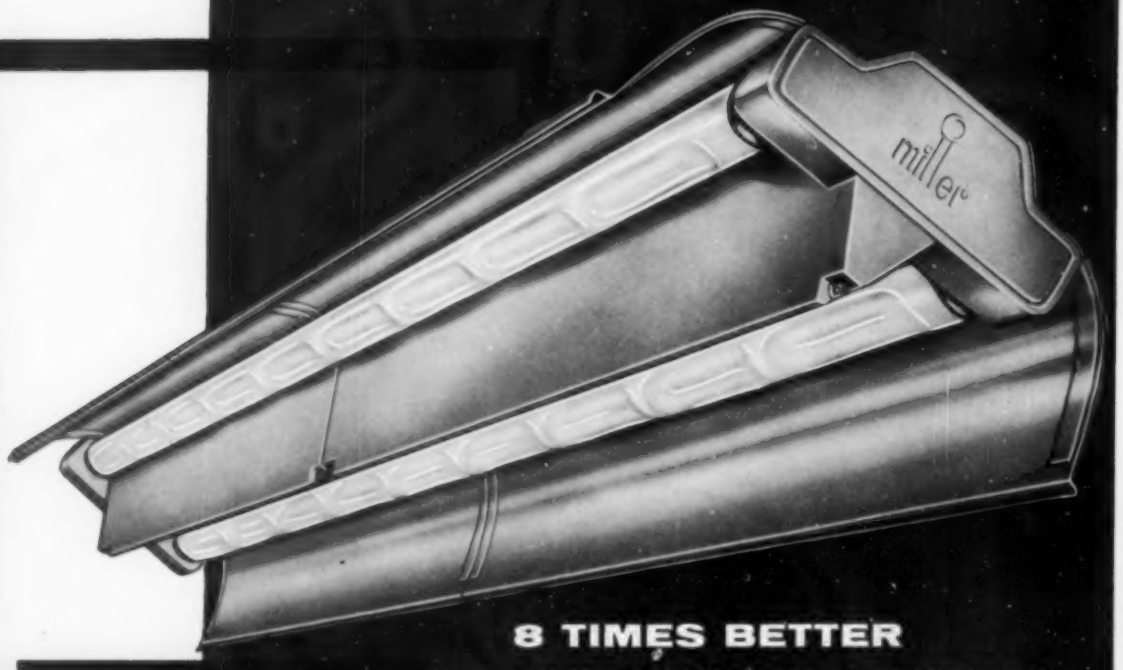
FLUORESCENT RLM

SMOOT-HOLMAN

INGLEWOOD, CALIFORNIA

We support the National Lighting Bureau

service in the west and southwest for all school, commercial and industrial lighting



8 TIMES BETTER BRIGHTNESS CONTROL WITH NEW POWER-GROOVE FIXTURE

THE NEW MILLER INDUSTRIAL IP 2501-08

- Alzak aluminum reflector
- 35° crosswise shielding
- 25% upward light

Now, with this new 8′ Miller fixture, you can efficiently harness the 26,000 lumen output of two G-E Power-Groove fluorescent lamps. It provides seeing comfort while enabling users to obtain high levels of light with fewer fixtures. The key comfort feature is the specially designed Alzak aluminum reflector with 35° crosswise shielding. *This limits brightness within the shielded zone to less than ⅛ that of comparable fixtures with porcelain enamel finish!* A 25% upward light component gives comfort a further assist by helping to control brightness contrasts. And the ventilated open top has a "self-cleaning" action which helps keep light output high and maintenance costs low. A louvre with 30° lengthwise shielding is available.

miller

Miller is the *first* major manufacturer to market an all-new fixture for use with Power-Groove lamps. For further information, contact your representative, or write:

THE MILLER COMPANY, DEPT. IPG-5, MERIDEN, CONNECTICUT

(*Continued from page 20A*)

The appointment of **Richard N. Vershure** and **Gabe Rice** as sales representatives of the John C. Virden Co., Cleveland, has been announced. Mr. Vershure has been assigned the Michigan territory and Mr. Rice will cover Southern Ohio, Kentucky and West Virginia.

The appointment of **H. Page Woodbury** as sales supervisor for lighting products in the New York section of the Metropolitan district has been announced by Sylvania Electric Products, Inc. In his new post, Mr. Woodbury will be responsible for the direction, supervision and administration of the lighting field sales activities in the area bounded by New York City, Poughkeepsie, N.Y., and Bridgeport, Conn. He will continue to make his headquarters at Sylvania's district sales office, 1000 Huyler St., Teterboro, N. J.

Sylvania's Lighting Division also announces the appointment of **Robert Houston** as lighting sales supervisor for the northern New Jersey area, with his headquarters in Teterboro. Prior to this appointment, Mr. Houston had been a sales representative for the lighting division.

Federal Sign and Signal Corp. has promoted **Don F. Feerer** from general manager of the company's electrical advertising division to vice-president. Mr. Feerer has his headquarters at the company's general offices in Chicago.

Sylvania-Corning Nuclear Corp. has announced plans to build at Hicksville, N. Y. a facility to produce atomic fuel elements for reactors used in research and electric power generation. The proposed 25,000 square foot plant is planned for a three-acre site adjacent to the company's present pilot-plant operation. **John C. Robinson,** commercial fuel manager at the pilot plant, will be in charge of operating the new production plant.

Henry Kogel, Staff Engineer, Society of Motion Picture and Television Engineers, has resigned to accept a position with Century Lighting Co., where his activities will be chiefly in the field of television studio lighting.

Light and Power Utilities Corp., Memphis, Tenn., have announced the promotion of **Nathan Tamm** to the position of vice-president. Mr. Tamm was production manager for the company since 1953. Also announced were the appointments of **Jim Clary** as sales manager and **Marshall Gerber** as office manager.

BOOKS AND PAMPHLETS

Heating, Ventilating and Air Conditioning Guide, 1957, 35th edition, published by the American Society of Heating and Air-Conditioning Engineers, 62 Worth St., New York 13, N. Y. Over 1250 technical data pages, 6 x 9-inch, cloth bound. $12.

Essential features of appearance, format and arrangement of previous editions have been preserved in the 1957 issue. The enlarged Technical Data Section reflects the growth in available technical information and the completion of several projects by Technical Advisory Committees of ASHAE. Much of the information has been obtained at the ASHAE's Research Laboratory at Cleveland.

Annual Report, 1956: NBS Miscellaneous Publication 220, available from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. 158 pages, 60 cents.

This report summarizes the research and development activities of the National Bureau of Standards in the physical sciences during the fiscal year 1956. Brief descriptions are given of representative accomplishments in each area of the Bureau's responsibilities, which include maintenance of basic standards, determination of physical constants and properties of matter, development of methods and instruments of measurement and the provision of calibration, testing and scientific advisory services.

The Annual Report is composed of five sections: (1) a general review or summary, (2) a resume of the Bureau's research and development work in progress or completed during 1956, (3) a review of the testing and calibration program, (4) a discussion of the Bureau's various cooperative activities, and (5) an appendix consisting primarily of statistical and organizational material and a complete list of publications by NBS staff members for the fiscal year.

Foreign remittances must be in U. S. exchange and should include an additional one-fourth the publication price to cover mailing costs.

Proceedings of the Second RETMA Conference on Reliable Electrical Connections, published by Engineering Publishers, GPO Box 1151, New York 1, N. Y. 103 pages, paper bound, $5.

The second RETMA Conference was sponsored last September by the Radio-Electronics-Television Manufacturers Association and the Department of Defense Advisory Group on Electronic Parts, with the cooperation of the University of Pennsylvania. This book, the Proceedings of the meeting, covers techniques, tools, materials and measurements of electrical connections. It includes 13 papers, with supplementary data and information from 23 other experts.

Engineering Enrollment in the United States, published by New York University Press, Washington Square, New York 3, N. Y. $7.50.

Edited by Norman N. Barish, Professor and Chairman of Industrial and Management Engineering at New York University, this book aims at giving a clear picture of the nature and magnitude of the engineering manpower problems in the United States. Basic statistics on enrollment trends in engineering schools and possible interpretations of these trends are given.

Seven Steps to Safety, published by the National Safety Council, 425 North Michigan Ave., Chicago 1, Ill. Single copies on request.

A digest of the Council's previously published 8-page booklet, "Plus Costs of Accidents," this one-fold leaflet outlines the seven basic principles of industrial safety.

I Want to Know About the Electric Industry, published by Edison Electric Institute, 420 Lexington Ave., New York 17, N. Y.

The 1957 edition of this annual booklet gives the latest available figures on the electrical industry. A new question on atomic energy in this edition — ninth in the series — brings to 29 the number of questions which the booklet answers.

NEW MEMBERS

At the meeting of the I.E.S. Joint Council April 17, in New York City, the following were elected to membership. Names marked * are transfers from Associate Member Grade.

ALABAMA SECTION

Member:

*Keyser, J. T., Jr., Alabama Power Co., Birmingham, Ala.

ARIZONA SECTION

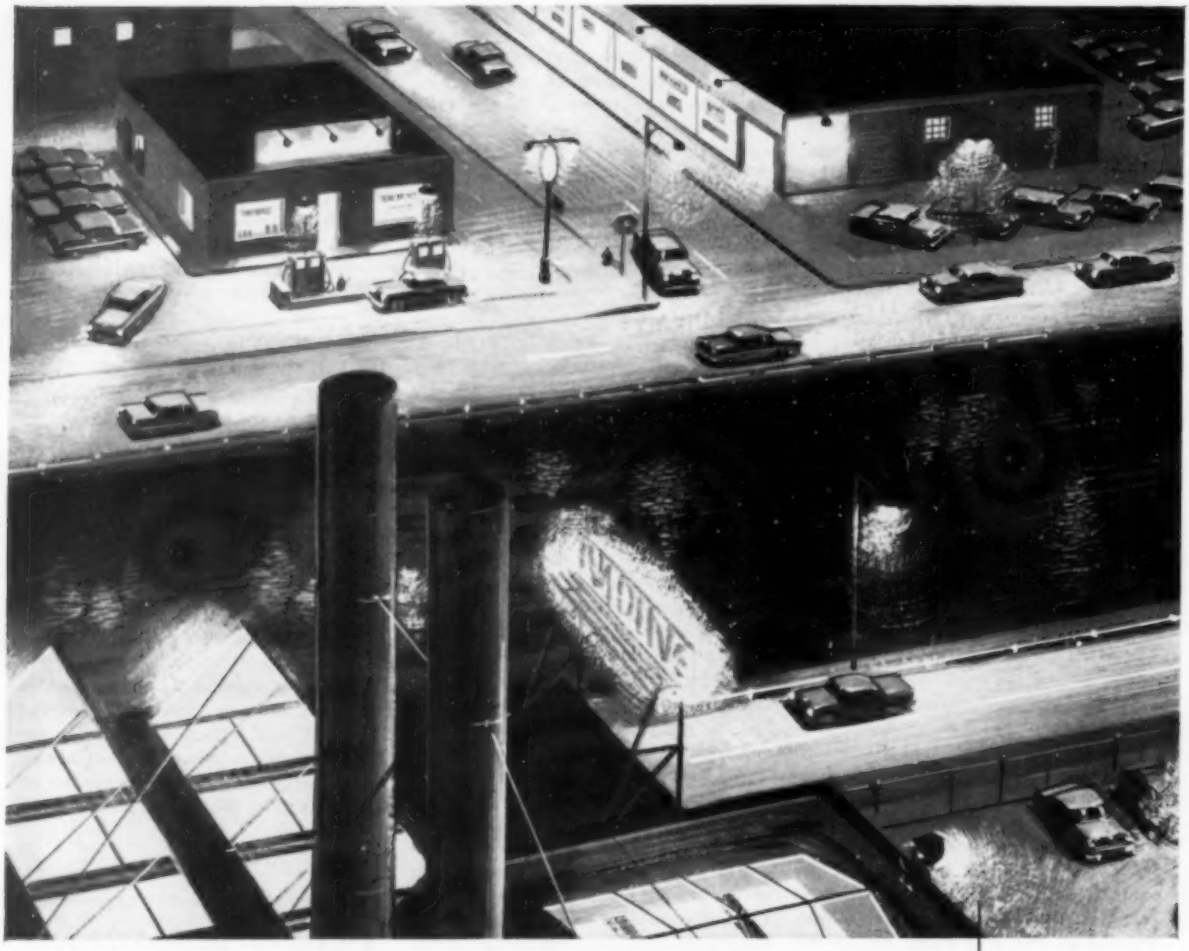
Associate Member:

Wetmore, A. V., Arizona Public Service Co., Flagstaff, Ariz.

(*Continued on page 40A*)

INDOORS AND OUT

LAMPS ARE IN SERVICE THAN



They're Job-Tailored to give you the most mercury light for your money

From Westinghouse developments like those below, you can see how the built-in quality of Westinghouse Mercury Lamps gives *more light when new, more light throughout life, as well as guaranteed long life.*

- Thorium-Coated Electrodes provide HIGHER LIGHT OUTPUT
- Molybdenum Ribbon Seals assure GREATER DEPENDABILITY, LONGER LIFE
- Hi-Temp Life-Time Bases eliminate INSTALLATION AND SERVICE BREAKAGE
- *Weather Duty® construction with special "hard" glass. Outside installations can't be harmed by snow, sleet or rain even when lamps are installed without protective coverings . . . or inside by fumes, or dripping condensation.*

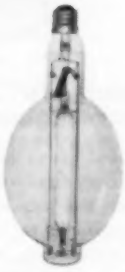
For recommendations for using the most complete line of mercury lighting—for the right kind of lamp for the job—call your nearest Westinghouse lamp supplier or write: *Westinghouse Lamp Division, Dept.* T1, *Bloomfield, N. J.*

B-H18: 700 W. Fluorescent-Mercury Lamp. Color-corrected Golden-White light for general purposes, flood and street lighting. A Westinghouse exclusive.

YOU CAN BE SURE...IF IT'S Westinghouse

MORE WESTINGHOUSE MERCURY
ALL OTHER BRANDS COMBINED

E-H1: 400 W. Mercury Lamp. Most widely used today. For interior and street lighting. **E-H1-Y:** Built-in clear yellow filter warns of road hazards.



A-H12-WD; A-H15-WD:1,000W. Weather Duty Mercury Lamp. Recommended for all interior and exterior applications. Widely used for industrial high bay lighting. Weather proof for heavy duty service.

A-H1-WD: 400 W. Weather Duty Mercury Lamp. Recommended for general purposes, flood and street lighting. Weather proof for heavy duty service.

P-H1: 400 W. Semi-Reflector Mercury Lamp. Color-corrected Golden-White for all interior uses. Ideal for areas of high dust concentration.

C-H12-WD; B-H15-WD:1,000W. Weather Duty Fluorescent-Mercury Lamp. Color-corrected Golden-White light for general interior and floodlighting. Weather proof for heavy duty service.

J-H1: 400 W. Fluorescent-Mercury Lamp. Golden-White light is color-corrected for interior and street applications. **J-H1-Y:** Rich, yellow light to identify road hazards. Ideal substitute for sodium installations.

SOUND CONTROL CAN BE A MAJOR FACTOR IN FLUORESCENT INSTALLATIONS . . . HERE'S HOW TO PLAN IT RIGHT

In many installations — particularly in hospitals, libraries, schools, churches, private offices and homes — noise is a *critical* factor. Ballast hum increases in proportion to the number of fixtures in a room. So, the greater the number of fixtures, the more urgent the need for ballasts with the *best* acoustical rating available.

There are six important reasons why Jefferson Ballasts are quieter, from an integral core structure which cannot vibrate within itself, to the complete performance tests prior to shipment. Use the sound control chart in the booklet offered here to select the proper Jefferson Ballasts for each room's characteristics. There you'll have satisfactory installations — and satisfied, happy customers.

Where sound control is important
Use Jefferson Rated Ballasts

WRITE NOW . . . FOR THIS SOUND CONTROL BOOKLET

Sound control charts and room characteristic information help you plan properly to eliminate complaints. No charge to the electrical trade. Just send name and address for your copy.

Jefferson BALLASTS

JEFFERSON ELECTRIC COMPANY • BELLWOOD, ILLINOIS

Perfeclite now offers a new **hammer lock** design in incandescent ceiling pan lighting fixtures. No other ceiling pan fixture on the market today has all these engineering features:

- Globe opens on **hinge** for quick easy cleaning and relamping.
- Unique **safety locking fitter** holds globe in place without bothersome screws, unsightly extensions or trick springs. Globe is secured with lugs by simple twist of the wrist.
- Lip of globe is completely protected against breakage by a **steel protector ring.**
- Provides **ceiling illumination** as well as **evenly distributed floor lighting.**
- Minimum amount of metal, maximum amount of glass results in **highest light efficiency.**

Here is a unique ceiling pan fixture design for either commercial or residential installation. For further information send for The Perfeclite Data Sheet 56-C today.

Perfeclite's new hammer lock fixture is available in the following sizes:

Model	Glass Diameter	Wattage
HH-9	8″	2- 40 W
HH-11	10″	2- 60 W
HH-13	12″	2- 75 W
HH-15	14″	2-100 W
HH-17	16″	3-100 W

Send for new Perfeclite Catalog 956 giving full information on our entire line of Commercial Incandescent Fixtures and Exit Units.

Fixtures are Underwriters Laboratories, Inc. approved.
*Patent pending

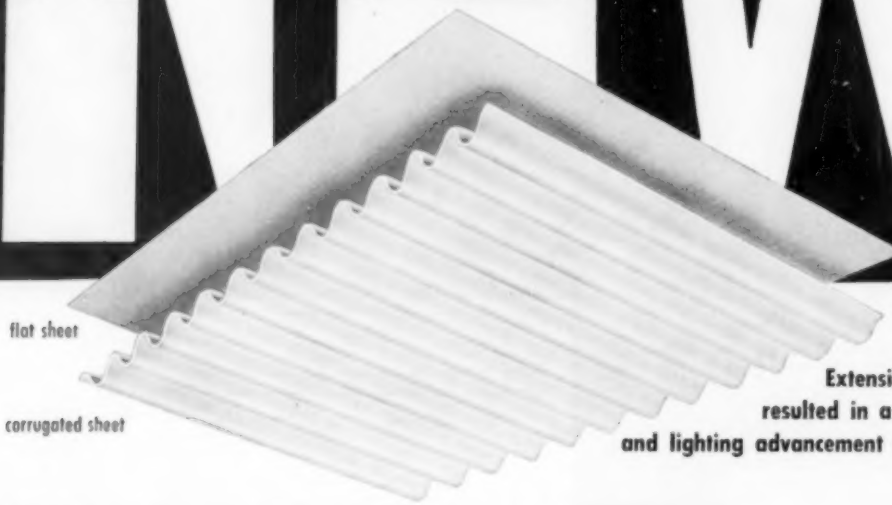
THE PERFECLITE COMPANY
1457 East 40th Street • Cleveland 3, Ohio

☐ Please send me The Perfeclite Data Sheet 56-C.
☐ Please send me the new Perfeclite Catalog 956.

Name.....
Address.....
City.....State.....

PERFECLITE PRODUCTS
THE MARK OF LIGHTING SERVICE

NEW



PATENT APPLIED FOR

Extensive research has now resulted in a combined acoustical and lighting advancement of great significance

SOUNDSHEET TRANSLUCENT ACOUSTICAL ELEMENT For Over-all Lighting Systems

For the first time, efficient *acoustical* properties have been combined with top quality illumination characteristics in a good-looking plastic laminate! Soundsheet by Contrex Company supplements other acoustical treatments, and can be effectively used with most wall-to-wall or area lighting systems now in existence or in the planning stage. Here are just a few advantages of Soundsheet:

- ★ BALANCED SOUND ABSORPTION — more at low frequencies than the average of commonly used types of acoustical treatment. Good absorption at the higher frequencies. N.R.C. — 0.70 by independent test for corrugated Soundsheet.
- ★ QUALITY ILLUMINATION — softly diffused lighting free of shadows and reflections at high efficiency.
- ★ EASY TO INSTALL — available in all standard widths; adaptable to most available over-all ceiling equipment, now installed or on order.
- ★ AVAILABLE NOW — in either corrugated or flat sheet — consult your lighting equipment manufacturer for use with his equipment.
- ★ LOW COST — initial and operating expenses — very little maintenance necessary — Soundsheet is completely washable.

Soundsheet harmonizes perfectly with any of today's architectural interior concepts. Contrex Company invites you to examine this new plastic laminate — Soundsheet — and learn more about its advantages and how they can benefit you.

Developed for Contrex by Bolt Beranek and Newman, Inc.

CONTREX COMPANY
CHELSEA 50, MASSACHUSETTS

MAIL TO:
CONTREX COMPANY
CHELSEA 50, MASS.

☐ Please send me literature and a sample of Soundsheet.

☐ Please have your representative call.

NAME_____

Company_____

ADDRESS_____

CITY_____ STATE_____

E-5

The thinnest fixture ever designed with no dark areas

the new Gibson Ceilo • 35

This beautiful surface-mount fixture is only 2¾" deep, the thinnest ever designed without panels or strips to conceal the ballasts. In the Ceilo-35, the ballasts are mounted in the sides, an exclusive Gibson development which provides a smooth, unbroken panel of light.

Not only is this new fixture the best-looking you ever saw, it has many new and practical design features to make installation faster and maintenance easier.

* * *

WRITE TODAY FOR COMPLETE INFORMATION

Makers of the world's most versatile fixtures

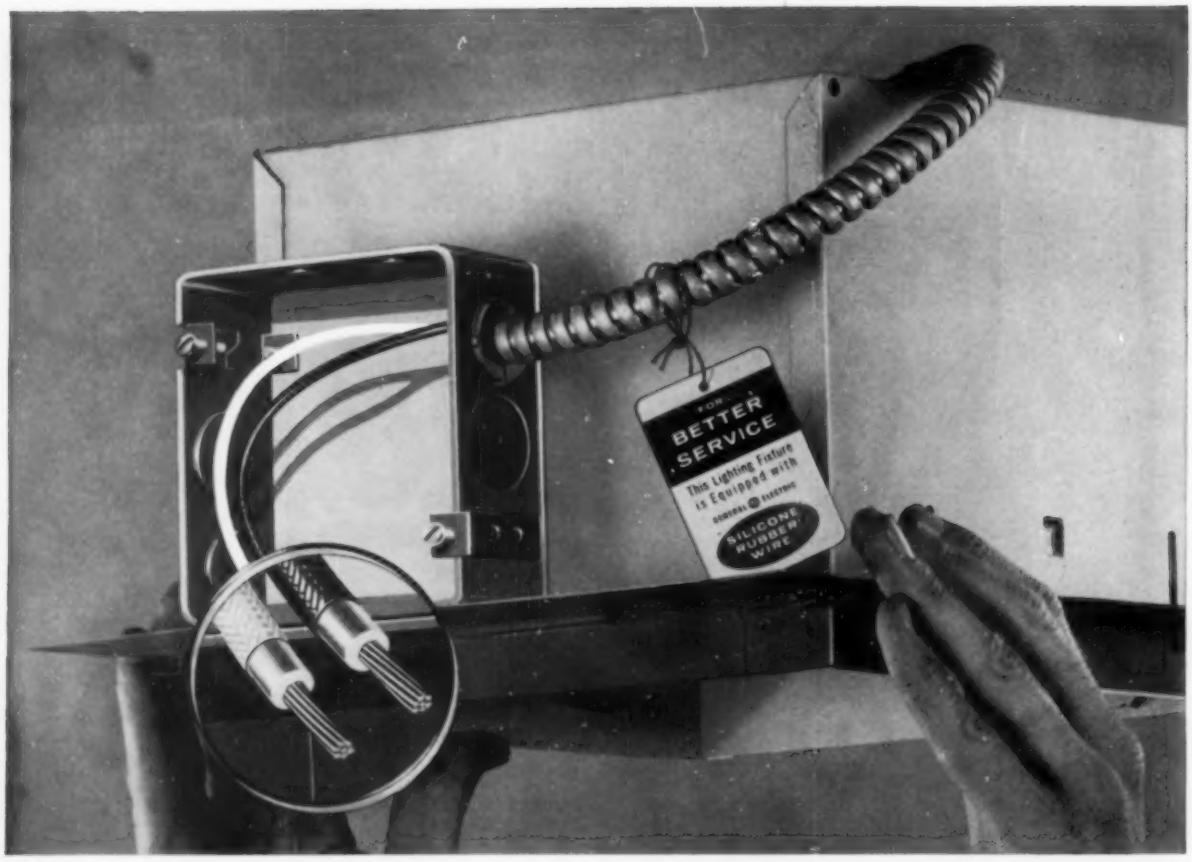
ortho-77® 88®

PAT. PEND.

Gibson LIGHTING

GIBSON Manufacturing Co.

1919 Piedmont Circle, N.E., Atlanta 9, Georgia



New fixture wire virtually ends breakdown from heat and moisture in recessed fixture leads

Everyone agrees that a good recessed lighting fixture must be good *throughout*. It must operate faithfully so that callbacks and customer complaints are kept to a minimum. Until now, a major source of trouble has been failure caused by breakdown of the insulation of the lead wires.

These failures were usually caused by a combination of excessive heat and moisture trapped in and around the fixture. The problem is solved by General Electric's new silicone rubber wire. It operates safely at conductor temperatures as high as 200 C. And it has excellent resistance to moisture and heat-aging as well.

Listed by Underwriters' Laboratories, Inc., G-E silicone rubber wire meets the acute demand for fixture wire rated at least 150 C for use in wet locations. Because it is flexible, clean-stripping, and easy to handle, G-E silicone rubber wire requires no special installation techniques.

SHOW THEM YOU'VE GOT IT—Just display this tag. It proves your fixture is protected by G-E silicone rubber wire against insulation failures due to heat and condensation. And you can give your fixtures an extra boost by taking advantage of G. E.'s free promotion folders to include in your fixture packaging. When you use G-E silicone rubber wire, the tag and the packaging folders are yours, for the asking, from General Electric.

FOR COMPLETE SPECIFICATIONS and a sample, write Section W130-578, Wire and Cable Dept., General Electric Company, Bridgeport 2, Connecticut.

Progress Is Our Most Important Product

GENERAL ELECTRIC

For general illumination, The Scott fixture by Sylvania provides soft, even light, has extremely high, 89.8%, illumination efficiency—giving a bonus in performance at no additional cost.

For close-work areas, mounting The Scott parallel to workers' line of vision brings maximum lengthwise shielding benefit into play. Lightweight plastic louver combines outstanding appearance with installation and maintenance features.

Supplementary lighting no longer needed...

Sylvania's Scott Fixture now provides precision lighting at Bendix Aviation

ENGINEERS WORKED OUT an unusual and successful lighting approach at the Eclipse Pioneer Division of Bendix Aviation Corp., Teterboro, New Jersey. In a semi-industrial area, they used a commercial-type fixture... Sylvania's *Scott* . . . to provide general illumination for precision motor assembly work.

Here The Scott does a double lighting job by eliminating the supplementary lighting system used previously:

1. **The Scott,** with its all-plastic reflector-shield, gives Bendix 110-116 footcandles of light at working level. It holds shadows and glares to a minimum, makes difficult seeing tasks easier.
2. **The Scott's** clean, attractive appearance harmonizes with the modern interior. Bendix personnel proudly show the installation to visitors as one more way Bendix protects the quality of its products.

Sylvania's *Scott* fixture offers many economies in both industrial and commercial applications. Because it has an exceptionally high, 89.8%, efficiency, *The Scott* will, in many cases, give the desired illumination levels with fewer fixtures—along with quality lighting.

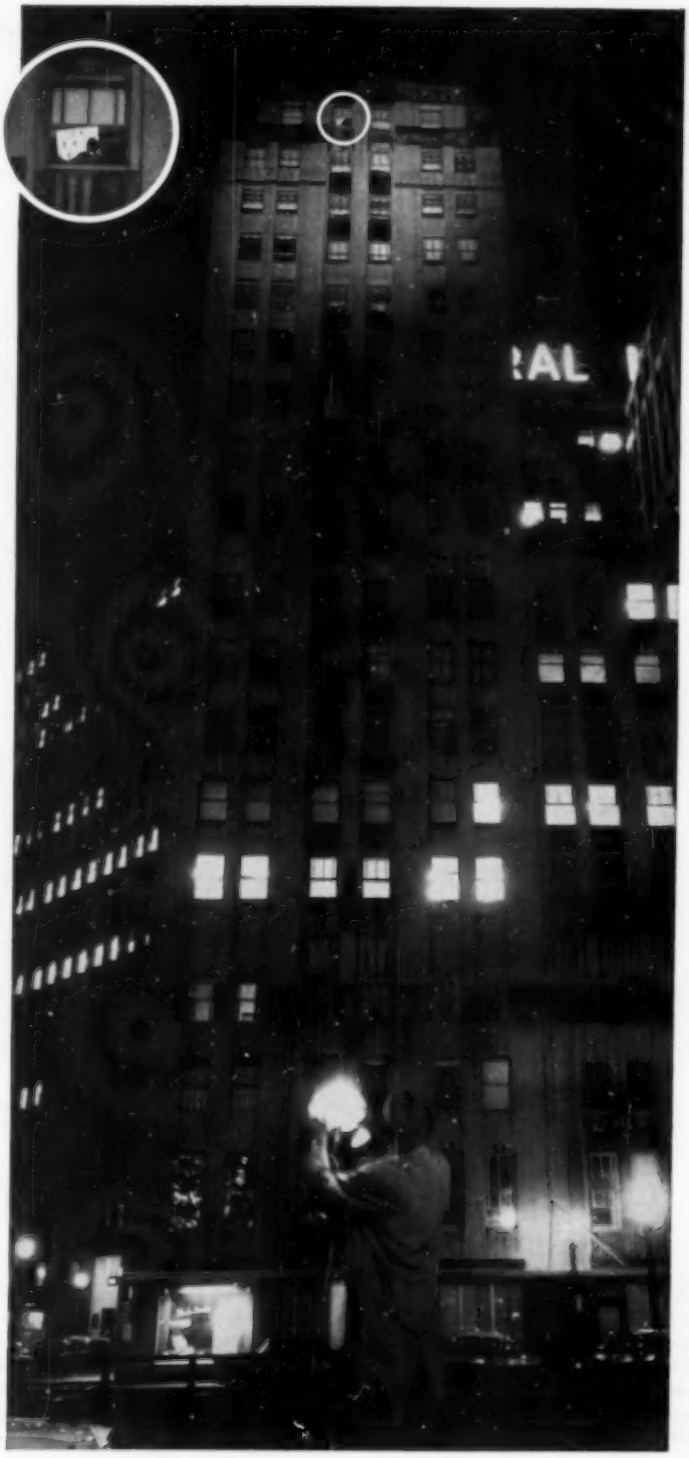
Next time you have an illumination problem either in industrial or commercial "close-work" areas, investigate the many advantages of lighting with Sylvania's *Scott*. For complete information, contact your local Sylvania Lighting Specialist, or write directly to:

SYLVANIA ELECTRIC PRODUCTS INC.
Department E-30,
Lighting Division—Fixtures
One 48th Street,
Wheeling, W. Va.

SYLVANIA
... fastest growing name in sight

LIGHTING • RADIO • TELEVISION • ELECTRONICS • ATOMIC ENERGY

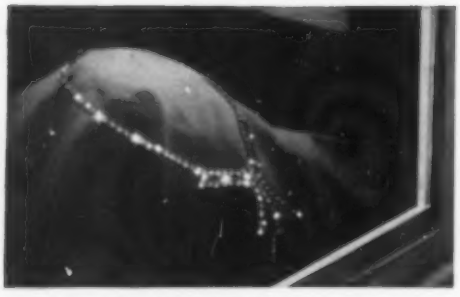
HE'S READING A PAPER 18 STORIES UP . . . by the light of one single 500-watt General Electric PAR Lamp! Never before could you get so much concentrated light in a self-contained lamp to do so many jobs. G-E 500-watt PAR Lamps in spot, medium flood or wide flood are the newest in a full line of General Electric lamps that give you just the right lamp for any spot or floodlighting job.



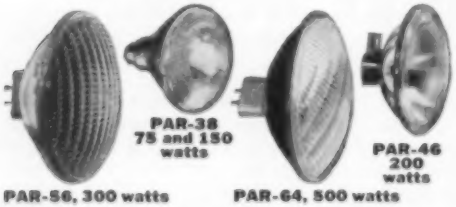
With G-E Par lamps you can

FLOODLIGHT 18 STORIES

or spotlight a diamond necklace



EVEN IN BROAD DAYLIGHT, a 150-watt PAR Lamp—3 feet away—brings out each lustrous detail of this beautiful necklace. Any merchandise from diamonds to dishes moves faster when it's given dramatic lighting.



VERSATILE—Nearly 30 combinations of sizes, beam patterns and colors are available. Sealed-in reflectors never need cleaning. Where the precision beam control of PAR Lamps isn't needed, see General Electric's full line of blown-glass reflector spots and floods at even lower prices. General Electric Large Lamp Dept., Nela Park, Cleveland 12, Ohio.

Progress Is Our Most Important Product

GENERAL ELECTRIC

G-E LAMPS GIVE YOU MORE FOR ALL YOUR LIGHTING DOLLARS

the Two Grand Old Names in Lighting *Announce* the New

Guth

Incandescent Lighting Catalog

"Mr. Holophane" says—

"Glad to have you aboard, Ed. My colleagues tell me your new catalog will prove to be most valuable for Architects and Engineers. Congratulations!"

CHARLES FRANCK,
President
The Holophane Company
New York 17, N. Y.

"Mr. Guth" says—

"Thank you, Mr. Franck. Our Engineers have had a hey-day with your grand lens-line. The new catalog appears to be a most helpful lighting tool."

EDWIN F. GUTH, SR.
The Edwin F. Guth Co.
St. Louis 3, Mo.

THE NEW GUTH CATALOG features 8 special indexed sections to completely cover the entire new Brascolite line of incandescent fixtures: square and round recessed units with Holophane Controlenses*, surface and suspended fixtures, night lights, bed lights, gym lights, etc. Complete with photograph of each fixture, plus specifications, dimensional drawings (drawn to scale for easy reproduction), coefficients of utilization, light curves, installation information and other technical data.

Also a special 12 page section including complete Lumen and Point-by-Point Charts, features of Guth quality design and construction, as well as description of the famous ALZAK Lifetime Aluminum Finishing Process.

Write on your letterhead for your complimentary copy of this new catalog today.

Celebrating
Our 55th Anniversary
1902-1957

*Holophane Co.

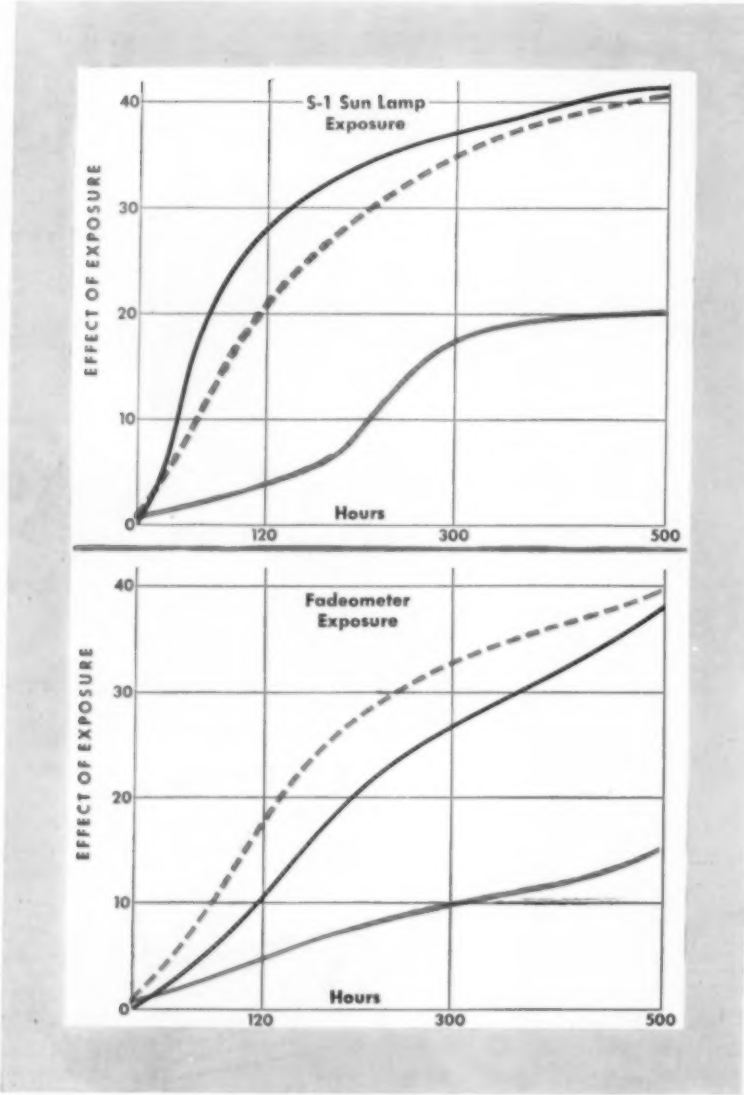
Guth brascolite

THE EDWIN F. GUTH CO., ST. LOUIS 3, MO.

Now, light-stabilized

EVENGLO® polystyrene

means light panels stay "new" longer



EVENGLO LIGHT-STABILIZED polystyrene, Koppers new formulation, resists discoloration due to illumination longer than other known light-stabilized polystyrenes. Fadeometer and S-1 sun lamp tests have proven this fact conclusively.

Fixtures Stay Young-Looking

Use of new EVENGLO light-stabilized polystyrene means that your shields, louvers, panels and fixtures will stay new and bright-looking far longer than ever before. Do you have a single customer who won't appreciate that important quality feature? To learn all the important facts on shaping, molding, extruding and processing new EVENGLO light-stabilized polystyrene, send in the attached coupon, today.

CHARTS AT LEFT show time (hours) vs. change (degrees) of discoloration—based on data obtained in Koppers laboratories.
Solid black line represents best of other known light-stabilized polystyrenes available December, 1956. Dotted red lines represent regular **Evenglo** polystyrene. Solid red lines represent improved light-stabilized **Evenglo** polystyrenes.

Koppers Company, Inc.
Chemical Division
Dept. IE-57, Pittsburgh 19, Pa.

Please send me your folder on EVENGLO light-stabilized polystyrenes.

NAME .....
COMPANY .....
STREET .....
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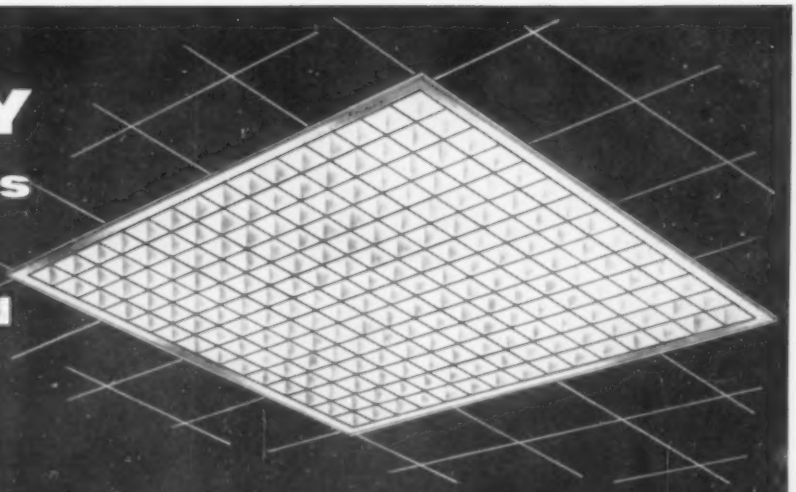
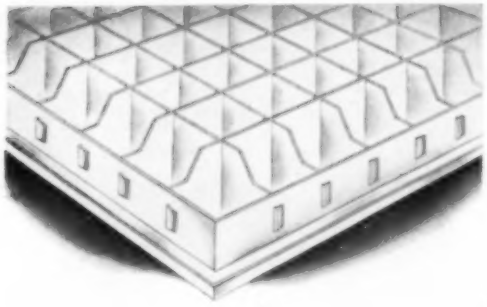
5600 series
4′ x 4′
Recessed Lighting



Lightweight one-piece louver
reduces fixture weight . . . adds strength

No Wavy Lines

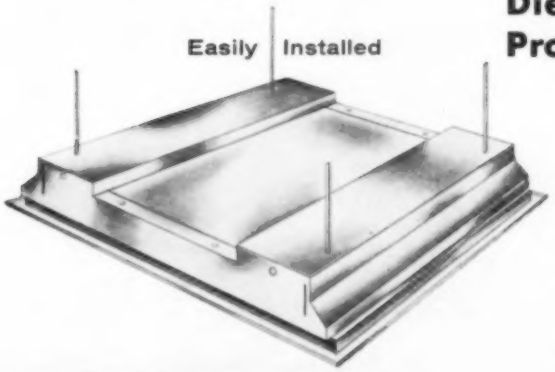


Unique One-Piece Framed Louver Cannot Sag or Lose Its Shape

Interlocking aluminum fins are rigidly locked into hinged frames. The total weight of this large area fixture is reduced by 25% imposing less burden on the ceiling.

Louvers cannot twist or bend out of alignment . . . no unsightly wavy lines. Small cell size provides soft, even lighting. Lamp placement in relation to louver fins assures even brightness, ample shielding.

Easily Installed



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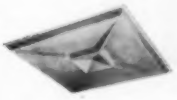

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Channel Screw Terminal Type
for T-8 Lamps

Channel "Quick Connect" Type
Rear Terminal Tabs for T-8 Lamps

Channel "Quick Connect" Type
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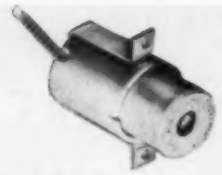

Slimline Plunger—Butt-on
High Voltage End Lead Terminal Type
—with or without mounting bracket
for Slimline Lamps

Medium—Single Screw Terminal
Type for T-8 and T-12 Lamps

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Type for T-8 and T-12 Lamps

Medium—Butt-on
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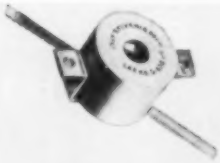
for T-8 and T-12 Lamps



Slimline Plunger—Butt-on
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Slimline Fixtures High Voltage End
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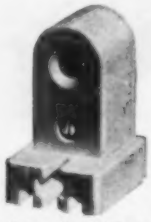

Slimline Fixtures Low Voltage End
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for Slimline Lamps

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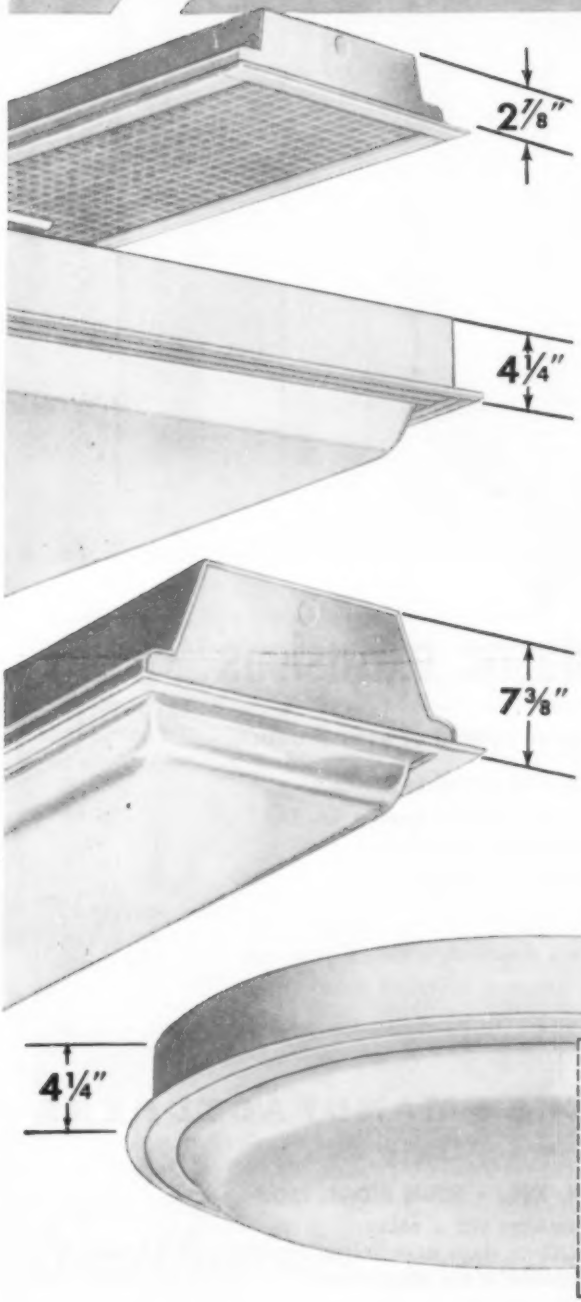

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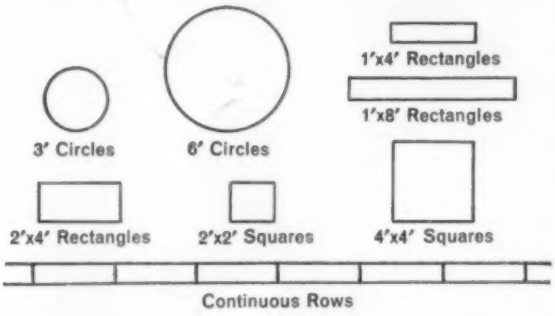

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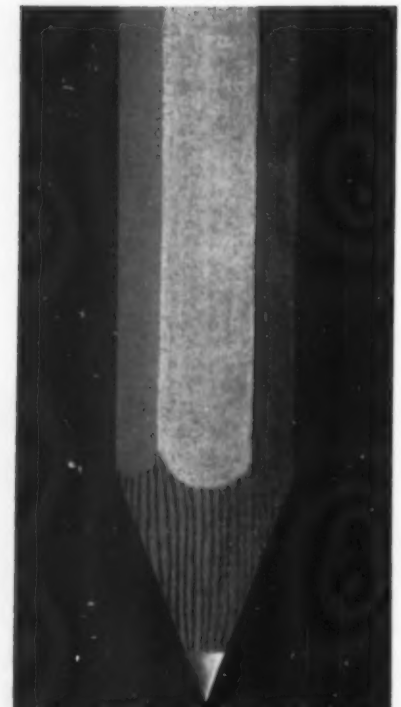

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(Continued from page 23A)

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(*Continued on page* 42A)

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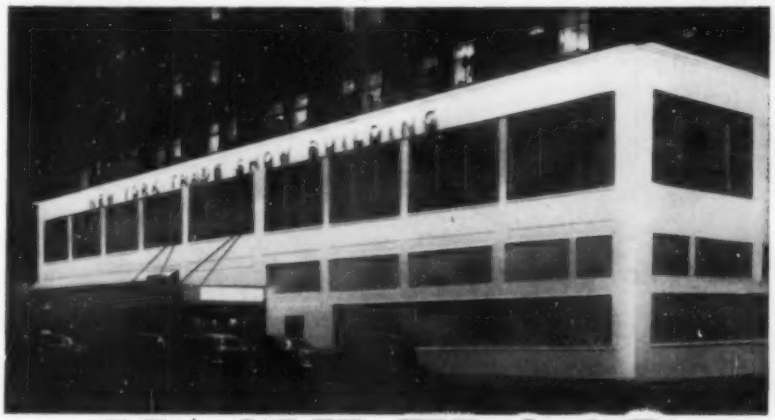

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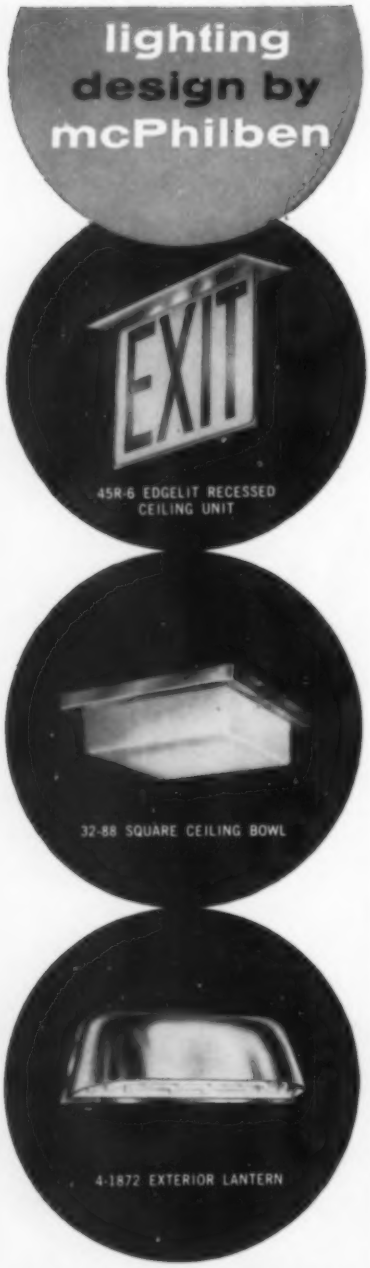

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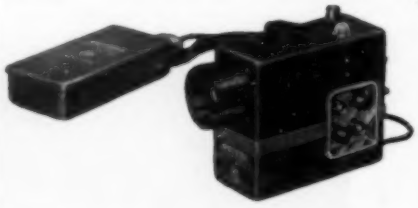

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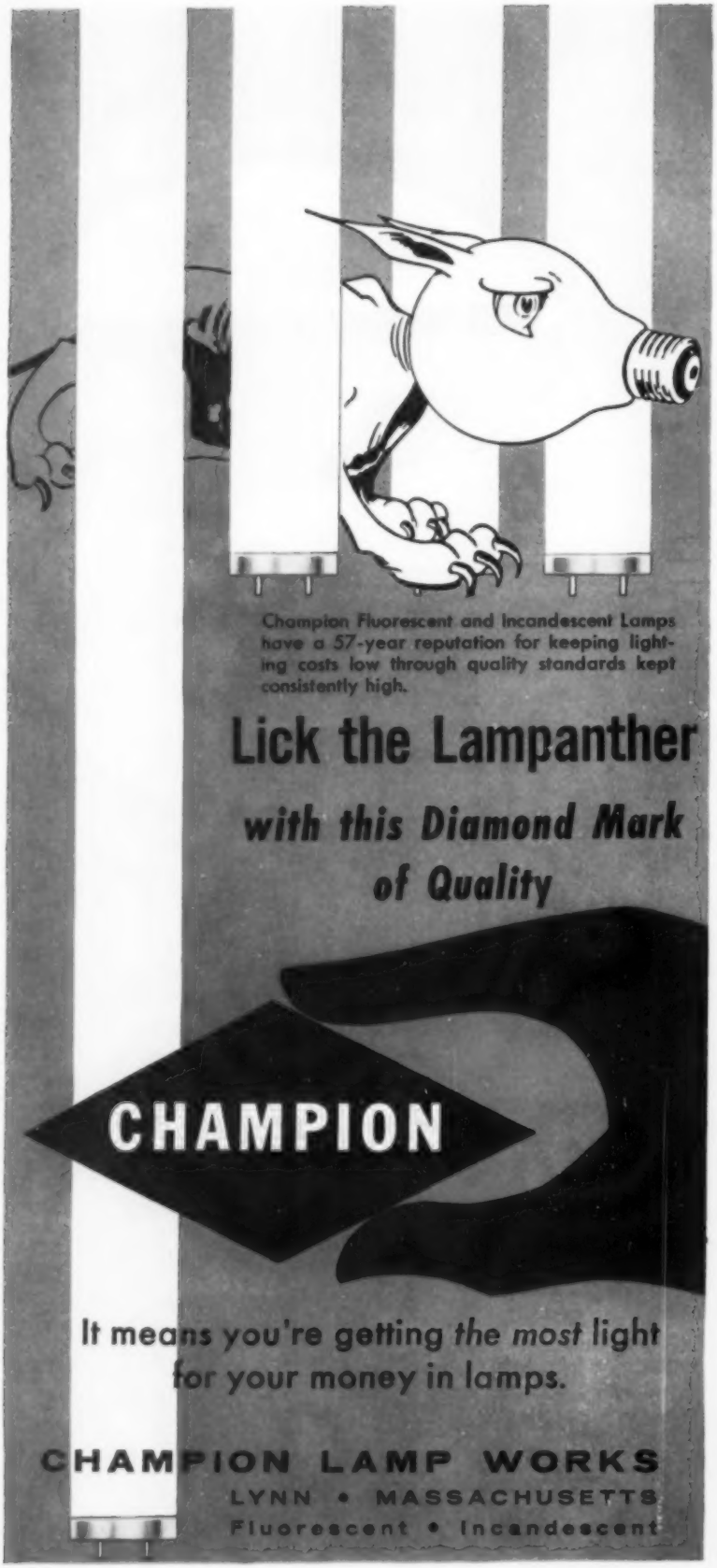
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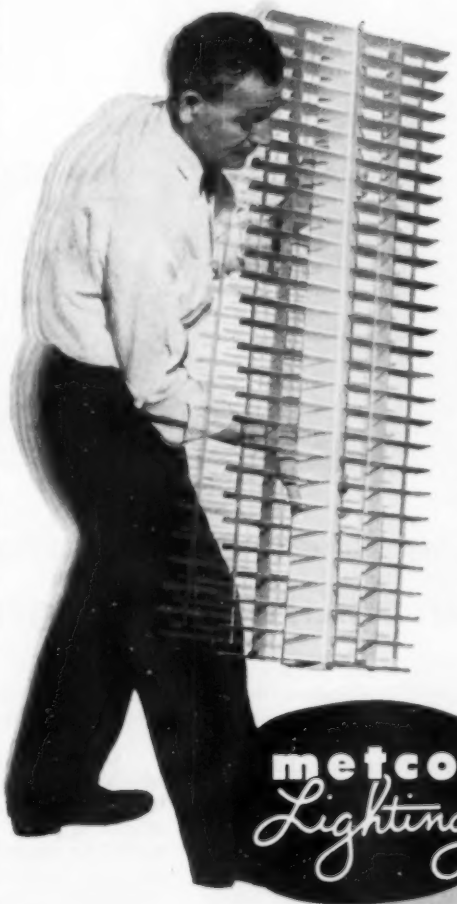

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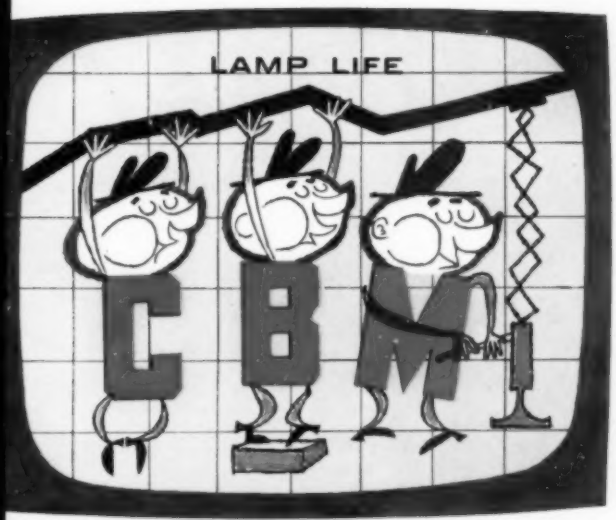

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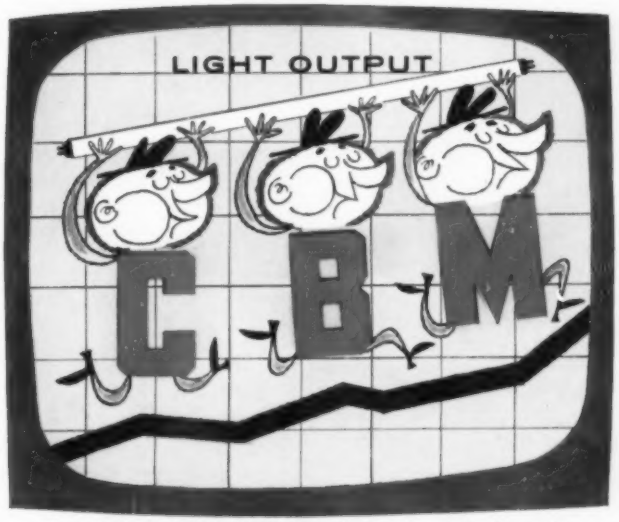

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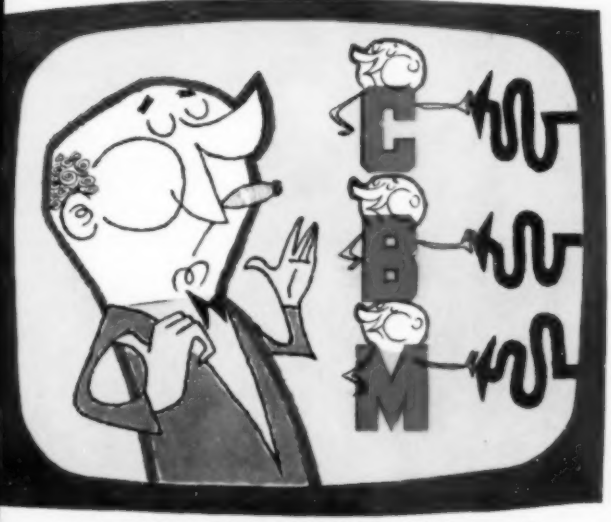

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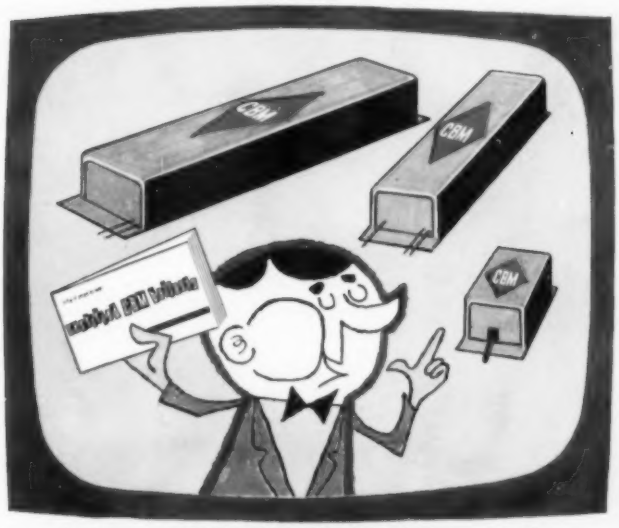

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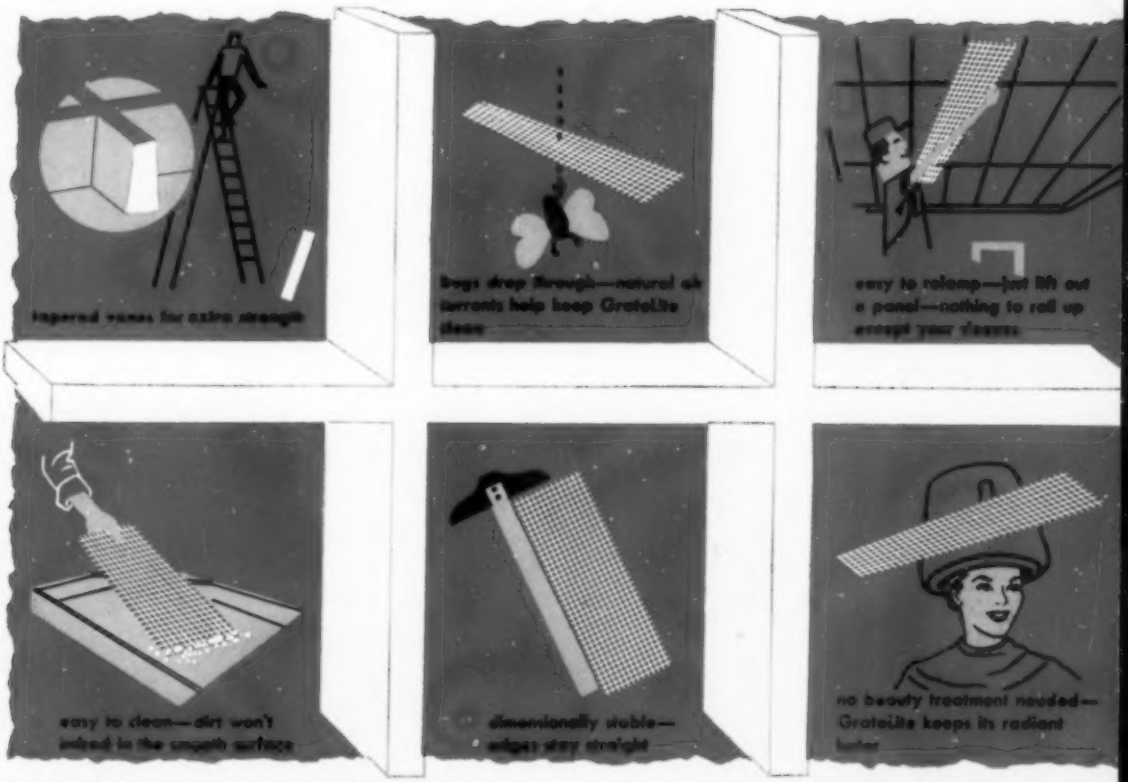
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